

Developments at Tenth International
Conference on Water Pollution Research
Held at Toronto, Canada on June 23-27, 1980

(U.S.) United States of America National
Committee for Representation of the US to the
International Assoc on Water Pollution Research

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16. ABSTRACT This report is an interpretive analysis of formal and informal developments at the Tenth International Conference on Water Pollution Research held in Toronto, Canada, on June 23-27, 1980. Pertinent conference developments are summarized and categorized as follows: modelling of lakes, pathogen removal, eutrophication, land disposal, methane fermentation, water-quality modelling and management, urban runoff, gas transfer, sludge treatment, toxic materials, biological wastewater treatment, nitrogen and phosphorus removal, physical-chemical treatment, water reuse, groundwater, and ocean disposal. Conference papers, complete with formal and informal floor discussions, will be published in the future.					
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Prepared For

**Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C.**

By

**United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research**

November 1980

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Re: EPA Grant No. R807269-01-1

Dear Mr. Carey:

In accordance with the provisions of EPA Grant No. R807269-01-1, awarded to the United States of America National Committee (USANC) for representation of the U.S. to the International Association on Water Pollution Research (IAWPR), USANC is pleased to transmit this report entitled "Developments at Tenth International Conference on Water Pollution Research," which includes an interpretive analysis of informal developments at the Conference judged to be of particular relevance to water quality control activities in the U.S.

The purpose of the EPA Grant, resulting in this report, was to promptly bring current water research developments from around the world to the attention of the EPA Office of Research and Development and other U.S. water pollution researchers. Specifically, this report is not simply a collection of papers presented at the Conference in Toronto, Canada, June 23-27, 1980, or merely an abstract or synopsis of papers but rather an analysis of formal and informal developments, including pertinent remarks, comments and ideas brought out in the discussion of papers and with researchers from throughout the world; representatives from thirty-nine (39) different countries attended the Conference. The formal papers and discussions of the Conference will be published as Proceedings in Progress in Water Technology. A total of thirty-two (32) engineers and scientists from the U.S. contributed in some way to the preparation of this report.

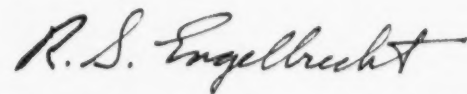
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10TH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH, TORONTO, CANADA — JUNE 23-27, 1980

Mr. Donald E. Carey
Page 2
November 20, 1980

The members of USANC sincerely appreciate the support provided by the Office of Research and Development which enabled the preparation of this report. Should there be any questions or need for additional information, please feel free to contact any member of the Coordinating Subcommittee.

Sincerely,



for USANC Coordinating Subcommittee

R. A. Conway
F. G. Pohland
D. G. Stephan
R. S. Engelbrecht, Chairman

rw

Attachment

CONTENTS

	Page
Letter of Transmittal	iii
Key to Reviews	viii
Executive Summary (Abstract)	xvi
I. Introduction	1
II. Individual Reports	4
<u>Sessions by Theme</u>	
a. Flotation, Gas Transfer, and Foam Fractionation (Including Paper Nos. 1, 2, 3) Reviewer: Leslie D. Lash	4
b. The Activated Sludge Process in Wastewater Treatment (Including Paper Nos. 4, 5, 6, 7) Reviewer: Makram T. Suidan	8
c. Biological Denitrification (Including Paper Nos. 8, 9, 10) Reviewer: Walter J. Weber, Jr.	17
d. Innovative Biological Treatment Processes (Including Paper Nos. 11, 12, 13, 14) Reviewer: Leo T. Mulcahy	24
e. Biofilm Models and Processes (Including Paper Nos. 15, 16, 17) Reviewer: David Jenkins	35
f. Physical-Chemical Means of Treatment of Wastewaters (Including Paper Nos. 18, 19, 20, 21) Reviewer: Donald B. Aulenbach	42
g. Chemical Treatment (Including Paper Nos. 22, 23, 24) Reviewer: Alan H. Molof	60

	Page
h. Solids Separation and Aeration (Including Paper Nos. 25, 26, 27) Reviewer: James H. Reynolds	73
i. Environmental Impacts in Marine Waters . . (Including Paper Nos. 28, 29, 30, 31) Reviewer: Clifford W. Randall	80
j. The Fate of Wastes Discharged into Coastal Waters (Including Paper Nos. 32, 33, 34) Reviewer: Mesut Sezgin	93
k. Measurement and Fate of Organics During Reclamation (Includes Paper Nos. 35, 36, 37, 38) Reviewer: Bruce E. Rittmann	109
l. Fate of Chemical and Microbiological Constituents in Different Water Environments (Includes Paper Nos. 39, 40, 41) Reviewer: Michael C. Kavanaugh	116
m. Industrial Wastewater Treatment (Includes Paper Nos. 42, 43, 44, 45) Reviewer: K. Daniel Linstedt	121
n. Heavy Metals Control and Subarctic Impoundment Problems for Water Quality Management (Includes Paper Nos. 46, 47, 48) Reviewer: Thomas H. Goodgame	137
o. Modelling of Lakes (Includes Paper Nos. 49, 50, 51) Reviewer: Charles R. O'Melia	143
p. Evaluation of Organism Removal from Waste- water Reclamation and Surface Waters . . . (Includes Paper Nos. 52, 53, 54, 55) Reviewer: Dale A. Carlson	150
q. Eutrophication (Includes Paper Nos. 56, 57, 58) Reviewer: Joseph F. Malina, Jr.	162

	Page
r. Contamination of Surface and Subsurface Systems from Waste and/or Waste Residue Disposal on Land (Includes Paper Nos. 59, 60, 61, 62) Reviewer: Riaz Ahmed	168
s. Effect of Toxicants on Methane Fermentation Reviewer: Frederick G. Pohland	182
t. Water Quality Modelling and Management (Includes Paper Nos. 64, 65, 66, 67) Reviewer: Roger A. Minear	188
u. Relationship between Urban Runoff Quality and Some Hydrological Parameters Reviewer: Frederick G. Pohland	196
v. Management and Control of Heavy Metals in the Environment Reviewer: Dipak Roy	199
w. Odour, Airborne Contaminants and Aerosols from Wastewater Collection and Treatment Reviewer: Gene F. Parkin	205
x. Groundwater Contaminants from Land Disposal of Residues Reviewer: Kevin J. Phillips	212
III. Overview of Pertinent Conference Developments	219
Developments at Formal Sessions	219
Developments Outside of Formal Sessions	226
Appendices	

KEY TO REVIEWS

<u>Paper No.</u>	<u>Title and Authors</u>	<u>Page</u>
1.	Assessing Flotation Behaviour of Different Types of Sewage Suspensions R. Gehr and J. G. Henry (Canada)	4
2.	Predicting Oxygen and Nitrogen Absorption Rates From Submerged Suspensions of Gas Bubbles . . . Torleiv Bilstad (Norway), Edwin N. Lightfoot (USA)	6
3.	Applications of the Bubble Fractionation to Water and Wastewater Treatment J. Mallevalle, M. Mietton, C. Tauzin, M. Roustan, H. Roques (France)	6
4.	A General Model for the Activated Sludge Process P. L. Dold, G. A. Ekama, G. V. R. Marais (S. Africa)	8
5.	The Effect of Particulate Organic Material on Activated Sludge Yield and Oxygen Requirements W. Gujer (Switzerland)	10
6.	The Role of Filamentous Microorganisms in Activated Sludge Settling M. Sezgin (USA)	11
7.	Evaluation of Operational Benefits to the Activated Sludge Process Using Step Feed Control Strategies P. E. Sorensen (Denmark)	13
8.	Industrial Waste Carbon Sources for Biological Denitrification H. D. Monteith, T. R. Bridle, P. M. Sutton (Canada)	17

<u>Paper No.</u>		<u>Page</u>
9.	Kinetic Model of Biological Denitrification in a Fluidized Bed Biofilm Reactor (FBBR) . . . L. T. Mulcahy, W. K. Shieh, E. J. LaMotta (USA)	19
10.	Kinetics of Biological Fluidized Bed Wastewater Denitrification J. P. Stephenson, K. L. Murphy (Canada)	20
11.	Denitrification of Water for Human Consumption Y. Richard, A. Leprince, G. Martin, C. Leblanc (France)	24
12.	Biological Nitrogen Removal by Step-Feed Process Y. Miyaji, M. Iwasaki, Y. Sekigawa (Japan)	26
13.	Continuous Bioregeneration of Granular Activated Carbon During the Anaerobic Degrada- tion of Catechol M. T. Suidan, W. H. Cross, M. Fong (USA)	28
14.	Bayer Tower Biology - An Efficient, Low Noise and Odor-Free Process for Biological Wastewater Treatment E. Schellmann (W. Germany)	31
15.	Nitrification Kinetics in a Rotating Biological Disk Reactor Y. Watanabe, M. Ishiguro, K. Mishidome (Japan)	35
16.	Practical Problems Related to Nitrogen Bubble Formation in Fixed Film Reactors P. Harremoes, J. La C. Jansen, G. H. Kristensen (Denmark)	37
17.	Design of Fixed-Film Processes With Steady-State Biofilm Model B. E. Rittman and P. L. McCarty (USA)	39
18.	A General Equilibrium Model for the Precipi- tation of Phosphate with Aluminium E. Arvin, G. Petersen (Denmark)	42
19.	Non-biological Elimination Mechanisms in a Biological Sewage Treatment Plant C. Matter-Muller, W. Gujer, W. Giger, W. Stumm (Switzerland)	46

<u>Paper No.</u>		<u>Page</u>
20.	Optimal Advanced Treatment and Phosphorus Removal by Deep Bed Filtration H. Gros and B. Morgeli (Switzerland)	49
21.	A Comparative Study of Various Coagulants for the Renovation of Secondary Effluent L. R. J. van Vuuren, G. G. Cillie', J. van Leeuwen, J. Prinsloo (South Africa)	52
22.	Lime Treatment of Wastewater: Development and Application of a Simple Graphical Technique for Predicting the Chemical Composition of Lime Treated Secondary Effluent H. N. S. Wiechers, R. E. Lowenthal, G. V. R. Marais (South Africa)	60
23.	Physico-Chemical Treatment of Wastewater-Control of Reagent Additions by Pollutational Load to be Treated P. Marchandise, J. P. Legendre (France)	64
24.	Flocculation of Waste Emulsions Using Polyelectrolytes C. Axberg, A. M. Wennerburg, P. Stenius (Sweden)	68
25.	The Use of Flow Contractions to Improve Clarifier Performance P. L. Silveston, J. F. Cordoba-Molina, R. R. Hudgins (Canada)	73
26.	Pilot Performance of Deep U-Tubes R. E. Speece, Daniel Gallagher, Charles Krick, Robert Thomson (USA)	74
27.	Performance of Finned Channel Separator N. Tambo, K. Hashimoto, M. Sugahara, T. Hasegawason, T. Onitsuka (Japan)	76
28.	Some Factors Involved in the Occurrence and Limitation of Algal Blooms in an Australian Estuary C. W. Heath, I. C. Smalls, D. Cannon (Australia)	80
29.	Application of Ecological Dynamics for Eutrophication Control in Kobe Harbor Area T. Morioka (Japan)	83

<u>Paper No.</u>		<u>Page</u>
30.	Long-Term Changes in Benthic Fauna Resulting from Sewage Sludge Dumping into the North Sea . H. Caspers (Germany)	85
31.	Variability of Bacterial Counts in Coastal Waters A. L. H. Gameson (UK)	87
32.	The Role of Bottom Deposits in the Oxygen Regime of a Polluted Estuary A. James (UK)	93
33.	Investigations into Sewage Grease Behavior in Coastal Waters A. Davidson, J. F. Easey, J. J. Varjavandi, K. M. Warner (Australia)	99
34.	Movement of Mercury from Minamata Bay into Yatsushiro Sea A. Kudo (Canada), S. Miyahara (Japan), D. R. Miller (Canada)	103
35.	Development and Application of a Technique for the Determination of the Molecular Mass Distribution of Organic Compounds in Water . . O. O. Hart (South Africa)	109
36.	The Fate of Organic Micropollutants Through an Integrated Wastewater Treatment/Water Reclamation System J. F. J. van Rensburg, A. Hassett, S. Theron, S. G. Wiechers (South Africa)	110
37.	Reactions of Ozone with Aromatics in Dilute Aqueous Solution: Reactivity and Biodegradability of Oxidation Products B. Léglise, B. Langeais, and M. Doré	111
38.	Removal of Mutagenic Compounds in Wastewater Reclamation System Evaluated by Means of the Ames <u>Salmonella</u> /Microsome Assay R. Denkhaus, W. O. K. Grabow, O. W. Prozesky (South Africa)	112
39.	Simultaneous <u>in situ</u> Determination of Dissolved Nitrogen and Oxygen by Gas Chromatography . . . L. M. Evison (UK), E. Tosti (Italy)	116

<u>Paper No.</u>		<u>Page</u>
40.	Study of Partially Neutralized Aqueous Aluminum Chloride Solutions, Identification of Aluminum Species and Relation Between the Composition of the Solutions and their Efficiency as a Coagulant J. Y. Bottero, J. E. Poirier, F. Fiessinger (France)	117
41.	Evaluation of Organic and Mineral Pollutants in Surface Water Under the Effect of Lagooning . F. Erb, J. Dequiol, A. Brice, J. l'Hopitaugh, A. Phillipdo, J. N. Pommerg (France)	118
42.	Activated Carbon Processes for the Treatment of Chromium (VI) - Containing Industrial Wastewaters A. R. Bowers, C. P. Huang (USA)	121
43.	The Removal of Nitrogen from an Inorganic Industrial Effluent by Means of Intensive Algal Culture F. Hendricks, J. Bosman (South Africa)	124
44.	Biological Nitrogen Control of Coke Plant Wastewaters T. R. Bridle, W. K. Bedford, B. E. Jank (Canada)	127
45.	Adsorption and Ion Exchange Processes for Treatment of White Water and Waste Water of Paper Mills C. H. Mobius (Germany)	132
46.	Inorganic Mercury-Bituminous Coal Sorption Interaction in Water M. P. Pandley, M. Chaudhuri (India)	137
47.	Water Quality Changes and Clearing Requirements for Impoundments in Arctic and Subarctic Regions D. W. Smith (Canada)	139
48.	Heavy Metals in the Ruhr River and their Budget in the Catchment Area Klaus R. Imhoff, Paul Koppe, Friedrich Dietz (Federal Republic of Germany)	139

<u>Paper No.</u>		<u>Page</u>
49.	Transport of Heat and Nutrients Across a Thermocline P. J. de Bruijn, L. Lijklema, G. van Straten (Netherlands)	143
50.	The Impact of Sewers on the Nutrient Budget of Lake George, NY D. B. Aulenbach, N. L. Clesceri, J. R. Mitchell (USA)	144
51.	Nonpoint Quantification and its Role in Lake and Stream Water Quality Planning R. Ahmed, R. Schiller (USA)	146
52.	Evaluation of Acid-Fast Bacteria, <u>Candida</u> <u>albicans</u> , Enteric Viruses and Conventional Indicators for Monitoring Wastewater Reclamation Systems W. O. K. Grabow, J. S. Burger, E. M. Nupen (South Africa)	150
53.	Inactivation of Enteroviruses by Ozone D. Roy, R. S. Engelbrecht, P. K. Y. Wong, E. S. K. Chian (USA)	153
54.	Study of a Pour Plate Technique for the Enumeration of Coliform Organisms in Surface Water J. Vial, Ch. Geoffray (France)	156
55.	Efficiency of Ultrafiltration for the Isolation of Enteric Viruses and Coliphages from Large Volumes of Water in Studies on Wastewater Reclamation E. M. Nupen, N. C. Basson, W. O. K. Grabow (South Africa)	158
56.	The Chemical Control of the Water Hyacinth (<u>Eichhornia crassipes</u> (Mart.) Solms) P. J. Ashton, W. E. Scott, D. J. Steyn (South Africa)	162
57.	The Stimulation of Autotrophic Production by Urban Stormwater-Borne Nutrients T. J. Grizzard, R. N. Waterman, C. W. Randall, R. C. Hoehn (USA)	164

<u>Paper No.</u>		<u>Page</u>
58.	The Sensitivity to Phosphorus and Nitrogen Loads, of Lake Rotorua, New Zealand R. A. Hoare (New Zealand)	165
59.	Lysimeter and Field Studies on Land Application of Wastewater Sludges M. D. Webber, Y. K. Soon, T. E. Bates (Canada)	168
60.	Operation and Design of Biological Leachate Treatment Plants R. Stegmann, H. J. Ehrig (West Germany)	171
61.	Treatment Effects and Pollution Dangers of Secondary Effluent Percolation to Groundwater . E. Idelovitch, M. Michail (Israel)	175
62.	Nitrogen Removal in a Subsurface System A. Andreoli, R. Reynolds, N. Bartilucci, R. Forgione (USA)	178
63.	The Response of Methane Fermentation to Cyanide and Chloroform J. Yang, R. E. Speece, G. F. Parkin, J. Gossett, W. Kocher (USA)	182
64.	Least-Cost Optimization for Area Wide (208) Wastewater Management Using Mixed Integer Programming K. J. Phillips, S. R. Kellogg, E. J. Beltrami, T. O. Carroll (USA)	188
65.	The Use of the Multidimensional Analysis in the Comparison of the 1976 vs 1971 Seine Basin Surveys Y. LeFoll, A. Lesouef (France)	190
66.	Combating River Pollution Taking the Rhine River as an Example C. van der Veen, J. Huizenga (Netherlands)	192
67.	The Application of the Biocenotic Model for the Prediction of the Effects of an Impoundment of Flowing Water M. Boes (Germany)	193
68.	Urban Runoff Quality in Finland and its Dependence on Some Hydrological Parameters . . M. J. Melanen, R. H. Laukkanen (Finland)	196

<u>Paper No.</u>	<u>Page</u>
Workshop I - Management and Control of Heavy Metals in the Environment	199
Workshop II - Odour, Airborne Contaminants and Aerosols from Wastewater Collection and Treatment	205
Workshop III - Groundwater Contaminants from Land Disposal of Residues	212

ABSTRACT

Beginning in 1962, the International Association on Water Pollution Research has held an international conference biennially. This report is an interpretive analysis of formal and informal developments at the Tenth International Conference on Water Pollution Research held in Toronto, Canada, on June 22 to 26, 1980, and has been prepared for the U.S. Environmental Protection Agency by the USA National Committee for Representation of the United States to the International Association on Water Pollution Research.

The Conference papers, complete with formal and informal floor discussion, will be published in the future. Because of this, this report does not contain the formal papers or verbatim presentations of discussions. Rather, this report was prepared by the official U.S. participants in the Conference as a critical analysis of formal and informal developments at the Conference which were deemed to be of potential interest to the U.S. Environmental Protection Agency.

Important information concerning developments in international water pollution research was obtained both from the formal Conference sessions, and, perhaps even more importantly, from informal information exchanged outside the formal meeting rooms. Of particular significance were the following:

- the need to consider both wind-induced entrainment and diffusive transport when determining vertical diffusion coefficients in lake modeling (Netherlands).
- the importance of direct atmospheric input of nutrients to lakes (USA).
- the need for incorporating transport/transformation processes in water quality modeling to lessen empiricism (several countries).
- the use of acid-fast bacteria as part of a battery of bacterial indicators of pathogens (So. Africa).

- the elucidation of the effects of pH, temperature, and residual concentration on ozone disinfection; high pH, high temperature, and high residual ozone (over 0.1-0.2 mg/L) favored disinfection (USA).
- definition of the efficacy and side effects of using a terbutryn herbicide for control of water hyacinth (So. Africa).
- successful use of sludges high in phosphorous-removal chemicals as fertilizer for grain and grass crops (Canada).
- the difficulty of leachate treatment in aerobic biological systems due to variable feeds; leachate recycle and land treatment are alternatives (Germany, USA).
- the marked reduction of toxicity to energy-producing anaerobic systems through use of an attached-growth reactor and/or acclimation (USA).
- the development of new statistical and deterministic models for water quality prediction in rivers (several countries).
- the multifactor correlation of urban runoff quality with rainfall variables in several areas (Finland).
- improved understanding of gas transfer kinetics in U-tube aeration devices (Norway, USA).
- improved means to conduct and scale-up flotation studies (Canada).
- new potential means for modifying the analysis of biological wastewater treatment systems to take into account the influence of particulate organic materials and endogenous respiration (So. Africa, Switzerland).
- additional data on the use of filament length to characterize activated-sludge settleability (USA).
- appreciable interest in nitrogen removal; nearly 15% of the papers presented at the conference concerned this topic.

- reliable models for fixed-film biological reactors require appreciable additional experimental work (USA, Canada, Denmark).
- successful substitution of many waste materials for methanol in biological denitrification systems (Canada).
- control of off-gases from biological wastewater treatment by use of exceptionally deep tanks to increase oxygen transfer and, thus, to reduce off-gas volume (Germany).
- use of autotrophic denitrification for potable water supplies (Canada).
- decreased rate of denitrification in fixed-film systems due to nitrogen bubbles produced during the course of denitrification (Denmark).
- presentation of a graphical means for predicting effluent quality from lime treatment (South Africa).
- suggestions for cost saving in phosphorus removal and in other physical-chemical treatment processes (UK).
- development and verification of a leachate migration model (Canada).
- practically useful design information on U-tube aerators (USA).
- new insights on the migration of contaminant-laden sediments from estuaries to the sea (Japan, Canada).
- reports of a new mutagen assay said to be more sensitive than the Ames test (South Africa).
- a novel rotating disk carbon adsorption device suitable for removal of hexavalent chromium (USA).

CHAPTER I

INTRODUCTION

Background

The International Association on Water Pollution Research (IAWPR) is a non-governmental professional organization with the goal of advancing water pollution research worldwide to enhance the quality of the earth's water resources. Through conferences, workshops, symposia, etc. and publications, e.g., Water Research and Progress in Water Technology, IAWPR provides a means for the international communication of research results and new information relative to water quality control. The organization is governed by representatives of national committees of member countries. Each national committee, as a condition of membership in IAWPR, represents the water quality research-related activities in the respective country; currently, 28 countries are members of IAWPR.

The United States of America National Committee (USANC) is recognized by IAWPR as the national organization representing U.S. water quality research interests in IAWPR. USANC is sponsored by five major professional organizations with interests in water quality research: (1) American Chemical Society; (2) American Institute of Chemical Engineers; (3) American Society of Civil Engineers; (4) Association of Environmental Engineering Professors; and (5) Water Pollution Control Federation. Each of these professional organizations provides a modest amount of financial support to USANC for membership in IAWPR and appoints two delegates and two alternate delegates to serve on USANC.

An international conference, sponsored by IAWPR, has been held biennially since 1962. Prior to the Tenth International Conference in Toronto, Canada, June 23-27, 1980, Conferences were held in London, Tokyo, Munich, Prague, San Francisco, Jerusalem, Paris, Sydney, and Stockholm. The 1982 Conference is scheduled for Cape Town, Republic of South Africa, March 29-April 2, 1982; Amsterdam has been selected as the site of the Twelfth Conference in 1984. The conferences represent the largest international gathering of research

engineers and scientists, consulting engineers, manufacturers of process control equipment, administrators of water quality control programs and others involved in some phase of water quality control.

The purpose of this report, prepared by USANC for the Office of Research and Development, U.S. Environmental Protection Agency, is not to present a verbatim record of the Conference. Papers complete with formal and informal floor discussion and responses from authors will, in time, be published as Proceedings in one of the two professional journals of IAWPR, Progress in Water Technology. Rather, the purpose of the report is to present a timely and critical analysis of formal and informal developments at the Conference which are of potential interest to EPA. The report represents an assessment by U.S. participants in the Conference of the significant developments at the Conference. Contributions of individual authors from various countries of the world are considered in the context of the reception which they received from discussers and the international audience. The analysis is not limited to formal conference developments, but includes developments from the informal exchanges between engineers and scientists from various countries which inevitably occur at such conferences outside of the formal sessions.

The technical program for the Toronto Conference was developed by the Program Committee of IAWPR from papers submitted from around the world in response to an invitation to submit papers covering a wide range of subjects, e.g., the ecology of natural waters, limnology, micropollutants, fish toxicology, marine and estuarine pollution, runoff from agricultural and urban areas, treatment of municipal and industrial wastewaters, sludge treatment, etc. Reprints of papers selected for the program were available to participants in advance of the Conference, and only abbreviated summaries of the papers were presented by the authors in Toronto. Formal discussers were selected prior to the Conference to prepare critical analyses of each paper. Additionally, appreciable informal discussion of the papers and of the formal discussions occurred. Appendix I contains the program for the Conference and provides additional information on the conduct of the sessions.

Report Development

This report was prepared by those U.S. participants in the Toronto Conference who presented papers, presented prepared discussions of research work described by others, chaired or recorded sessions and workshops, and/or participated in IAWPR Governing Board activities and who elected to participate in

the project. Development of the report was coordinated by a Subcommittee of USANC consisting of the USANC officers for 1978-1980 (R. S. Engelbrecht, Chairman; D. G. Stephan, Vice-Chairman; R. A. Conway, Secretary-Treasurer); the Chairman of USANC for 1980-1982 (F. G. Pohland) assisted in finalizing the report as a member of the Coordinating Subcommittee.

Prior to the Conference, the USANC Coordinating Subcommittee ascertained the interest of Conference participants in contributing to the development of this report and solicited expressions of interest in reviewing particular sessions at the Conference (Appendix II). Assignments for coverage of all the sessions were then made as indicated in Appendix III. Appendix IV contains the instructions given to participants for the development of this report.

Reports by the individual participants are included in Chapter II. Aside from minor editing to render the reports compatible with the general format and to eliminate items unrelated to water quality research, the reports are published here as received from the authors. Thus, the reports represent a critical assessment by U.S. water quality control researchers and other professionals of those sessions of the Conference which received their special attention. The individual reports appear under the by-line of the reviewers and represent their personal views -- not necessarily the views of the Coordinating Subcommittee or USANC.

Highlights of Chapter II, as perceived by the Coordinating Subcommittee, are summarized in Chapter III. In addition, information submitted by individual participants on developments at the Conference unrelated to their sessions are summarized in Chapter III. The Executive Summary is an abbreviated version of Chapter III.

Users of the report will find the Table of Contents together with the Key to Reviews useful in locating in Chapter II the discussions of particular papers or workshops. Additionally, Appendix I should be useful in gaining a perspective on the Conference and on the contents of Chapter II.

CHAPTER II

I. SESSION

- A. Day: Monday, June 23, 1980
Hall: A
Time: 2:00 to 4:30 pm
- B. Theme of Session: Flotation, Gas Transfer, and Foam Fractionation

II. REVIEWER

- A. Name: Leslie D. Lash
- B. Position and Affiliation: Consultant,
Salt Lake City, UT

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 1: "Assessing Flotation Behaviour of Different Types of Sewage Suspensions Suspensions," by R. Gehr and J. G. Henry (Canada)

Significant in this work and of practical usefulness in further U.S. work are:

1. Use of a dissolved oxygen (D.O.) probe for direct measurement of air available for flotation.
2. Development of thickening parameters which removed the effect of
 - a. variation of influent suspended solids (ss) and
 - b. change of recycle volume ratio — on the relationship between float thickness and air to solids (A/S) ratio.

First, a D.O. probe in the pressure vessel of the 3-cell batch flotation apparatus eliminates the necessity of estimating the fraction of air dissolved (compared with the amount of air dissolved under theoretical conditions at that temperature and pressure). This presupposes accurate readings of the D.O. probe under high pressure, adequate mixing, etc., which are probably attainable.

Others have utilized bubbling of air through a pressurized vessel for a sufficient length of time to achieve saturation. (This could lead to a change in molar ratio of nitrogen to oxygen as discussed by Bilstad in Paper No. 2, but the effect could be insignificant).

Second, a thickening parameter, T.P., is developed

$$T.P. = \frac{\text{effective times thickened}}{A/S} = \frac{F/S_e}{A/S}$$

$$\text{Where } S_e = \frac{\text{influent SS concentration} \times \text{influent volume}}{\text{influent volume} + \text{recycle volume}}$$

and F = float solids concentration

$$\text{Then } T.P. = \frac{F (V_s + V_r)}{A}$$

Where V_s and V_r are the volume of suspension and recycle, respectively. The equation includes the amount of recycle but no longer has feed solids as a variable. A/S is air-to-solids ratio.

Two types of relationships were observed:

1. Plotting effective times thickened, that is, F/S_e , versus A/S ratio resulted in a linear curve through the origin. Thus, T.P. would be constant for a given waste (independent of feed). T.P. would then be helpful in quantifying the flotability of a waste (the higher the T.P., the thicker the float for a given air input). This is a welcome correlation for removing variables from batch characterization procedures and focusing on the variables of interest.
2. Plotting effective times thickened versus A/S ratio resulted in a significant intercept. A thickening equation (T.E.) could then be developed by linear regression of effective times thickened and A/S :

$$\text{effective times thickened} = m (A/S) + b$$

Note that the former thickening parameter equation is a simplified version of the above equation without the intercept b .

As the discussor pointed out, the relations are empirical and should not be used outside the applicable range. However, it is felt these will be most helpful relationships if used in the proper (experimental) range. The authors observed accurate scale-up from batch to continuous operation, except for clarity (turbidity) which was improved on the continuous unit.

- B. Paper No. 2: "Predicting Oxygen and Nitrogen Absorption Rates From Submerged Suspensions of Gas Bubbles," by Torleiv Bilstad (Norway) and Edwin N. Lightfoot (USA)

The authors developed a method for determination of dissolved gases in liquids. This utilizes a Silastic membrane tubing through which the gases diffuse from the water. A helium gas carrier then carries the gases to be analyzed, such as nitrogen and oxygen, to a gas chromatograph. Calibration is by the Van Slyke method.

An article with information on this technique, entitled "Simultaneous in situ Determination of Dissolved Nitrogen and Oxygen by Gas Chromatography" is published in Progress in Water Technology, Volume 10, pp 519-531.

- C. Paper No. 3: "Applications of the Bubble Fractionation to Water and Wastewater Treatment," by J. Mallevialle, M. Mietton, C. Tauzin, M. Roustan and H. Roques (France)

Attempting to demonstrate bubble fractionation on a practical scale has proved difficult. This is unfortunate, as the method could prove beneficial for removal of microconstituents, especially color.

Key to the technological problem is the small column diameter (30 mm maximum and 20 mm optimum per author and discussor). Even distribution of (a large) flow to multiple columns is a challenge. A low pressure drop distribution system is needed. In reply to the Discussor, P. B. B. Vosloo (South Africa), the author indicated that the feed should be introduced "near the top - even the summit."

IV. CRITIQUE OF SESSION

All papers were well received - this despite the fact they ranged from applied batch and pilot tests through pilot U-tube confirmation of mass transfer coefficients to laboratory experimentation with bubble fractionation.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 1: Empirical correlations developed for flotation should significantly simplify lab to pilot plant scaleup and reduction of data with meaningful parameters.

Paper No. 2: Means suggested to overcome fish embolisms (use oxygen or enriched air rather than air in high-pressure (deep U-tube) aeration; or use a number of shallow pressurizations with air - to avoid changing the nitrogen to oxygen ratio.

Paper No. 3: Significantly, a way must be found to practically and economically design tubes and distribution systems for bubble fractionation to be applied industrially. It would also be beneficial to find a suitable complexing agent for heavy metal removal by bubble fractionation.

I. SESSION

- A. Day: Tuesday, June 23, 1980
Hall: A
Time: 9:00 am to 12:30 pm
- B. Theme of Session: The Activated Sludge Process in Wastewater Treatment

II. REVIEWER

- A. Name: Makram T. Suidan
- B. Position and Affiliation: Associate Professor of Environmental Engineering
Department of Civil Engineering
University of Illinois
Urbana, IL

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 4: "A General Model for the Activated Sludge Process," by P. L. Dold, G. A. Ekama, and G. v. R. Marais (S. Africa)

Ekama presented a mathematical formulation of the kinetics of organic material degradation and nitrification in single and multi reactor configurations at different sludge ages and operating temperatures. The kinetics of nitrification were based on classical Monod formulations with an added step for the solubilization of organic nitrogen. The major contribution of the model was in the approach selected in handling the kinetics of the degradation of the influent COD fractions. Four such fractions were recognized in sewage: (a) the readily biodegradable COD accounting for 20% of the total, (b) the slowly biodegradable particulate COD accounting for 60% of the total, (c) the unbiodegradable soluble fraction of 5% of the total and (d) the unbiodegradable particulate fraction of 15% of the total. The readily degradable soluble fraction was handled through a Monod formulation while the remaining degradable particulate material was considered to go through a saturation adsorption step followed by solubilization and ultimately utilization.

The authors advocated the use of a growth-death regeneration approach to replace the conventional microbial decay formulation. In this analysis the active mass was considered to undergo cell lysis at the daily rate of

62%. Eight percent of the lysed material was converted to a particulate residue while the remaining 92% resulted in slowly degradable particulate COD.

The mathematical model, as formulated, was applied to a number of process configurations that included cyclicly loaded single stage completely mixed activated sludge, six completely mixed activated sludge reactors in series, a contact stabilization process and, finally, a single stage denitrification process utilizing influent sewage as an energy source. In all instances, the correspondence between model predictions and the experimental data was remarkably close.

Masschelein (Belgium) and Arvin (Denmark) were both invited discussers on this paper. Masschelein warned about fitting a model to data and emphasized the importance of the use of fundamental relationships to describe the complex phenomena occurring in the activated sludge process. He also questioned the use of COD rather than BOD, TOC or even TOD. On the issue of microbial decay, he asked if lag periods were observed during the periods of cyclic loading since changes in environmental conditions often induce such a behavior in microorganisms. Marais (South Africa) indicated that only COD measurements will insure the integrity of energy balances and noted that the TOD measure is not feasible for solids.

Arvin questioned the adoption of an adsorption mechanism for the particulate organic matter rather than the use of the more accepted flocculation mechanism. He also mentioned that model constants are invariably a function of floc size and that the measurement of floc size may allow for the adjustment of such constants. Ekama agreed to the need for a flocculation enmeshment mechanism, however, he admitted that they have not been successful with such an endeavor.

The floor discussion focused on a number of interesting facets of the model. Stephenson (Canada) inquired about the feeding frequency effect on the model's predictive power. Ekama indicated that the model predictions were excellent at steady state, acceptable when the feeding and nonfeeding cycles were 12 hr and such but much poorer at 6 and 18 hr feed and nonfeed cycles. Sutton (USA) inquired whether the model distinguished between pre and post denitrification kinetics, a question to which Marais responded in the affirmative. Other questions pertained to the characteristics of the sludge.

B. Paper No. 5: "The Effect of Particulate Organic Material on Activated Sludge Yield and Oxygen Requirements," by W. Gujer (Switzerland)

The author presented a mathematical model of the completely mixed activated sludge process that incorporates separate mechanisms for the removal of influent dissolved and particulate organic matter. The model, as proposed, was intended to provide rational means for the prediction of sludge composition and sludge production and decay rates. In addition, the mathematical model included the capability for estimating time varying oxygen utilization rates during the activated sludge treatment of wastewater.

Gujer demonstrated through rational development that particulate organic material present in the primary effluent of domestic wastewater treatment plants is rapidly incorporated into the sludge flocs via a flocculation mechanism. Consequently, the organic contribution of particulate matter is rapidly reduced in the activated sludge process effluent. However, no corresponding rapid oxygen utilization is encountered due to the very slow degradation of these particulates. Dissolved organic matter, on the other hand, is more rapidly oxidized.

In spite of its simplicity, the author proposed the mathematical model as a tool for estimating the viable microbial fraction present in activated sludge cultures.

Jenkins (USA), the official discussor, commended the author on the rational approach adopted during the development of the mathematical model. His comments, however, were concentrated on the experimental methods used for the development of coefficients for the model and the scope of applicability of the calibrated model. The author used a nitrogen biomass content of 0.089 g N/g COD (a literature value for *Klebsiella aerogenes* grown at 2.4 day⁻¹ on a glycerol limited medium). Jenkins computed that if a value of the nitrogen biomass content of 0.066 g N/g COD (obtained by the discussor on two activated sludge bacteria grown at 0.2 day⁻¹ on a carbon limited glucose salt) is used rather than the value proposed by the author, the activated sludge COD will compute to be 32% influent particulates rather than the 65% value reported by the author. Jenkins referred to two other parameter values that the author seemed to have used without sufficient justification; these were the values of the nitrogen contents of the influent particles and the total activated sludge organic matter. Due to the sensitivity of the mathematical model to the values of the coefficients

used and the apparent need for an appreciable effort in experimentation and testing prior to the use of the model for the simulation of the activated sludge treatment of a specific wastewater, Jenkins concluded that the widespread application of this model will be impaired.

Gujer agreed with much of the analysis presented by Jenkins as to the sensitivity of the model to the selection of parameters and the nature of the influent wastewater. However, Gujer warned that during the verification of the model's predictive ability with experimental data only one value of the nitrogen content of the activated sludge was applicable because this parameter is sludge age dependent.

Discussion from the floor centered mostly on the role of particulate matter in the performance of activated sludge treatment processes. Andrews (USA) proposed that the elimination of the primary settling tank would be a natural extension of the author's work. Such an endeavor would result in a reduction in odor problems and an improvement in sludge settling properties. Andrews emphasized the need for two-stage activated sludge treatment when nitrification is needed because if nitrification is desired in a single-stage unit, then a long sludge age will be needed which will lead to the utilization of oxygen in the degradation of particulates and a reduction in methane production during anaerobic digestion. Garrett (USA) agreed with Andrews' recommendations and cited the case of the Houston Sewage Treatment Plant where an increase in sludge age resulted in improved degradation of the cellulosic type particulate material and, as a consequence of this change, the vacuum filter dewaterability of the sludge deteriorated appreciably. Esener (Netherlands) stated that a carbon material balance in addition to the nitrogen material balance would lend better credibility to the data. Gujer agreed with the need for an additional material balance to confirm the integrity of the data, however, he stated that a phosphorus material balance has been used in the work to confirm the results of the nitrogen balance. Sorensen (Denmark) stated that the mathematical model presented by Gujer predicted his experimental data rather well, however, when the feed suspended solids were increased due to the addition of the supernatant from sludge concentrators to the feed sewage, Gujer's model failed to handle the case of a high strength suspended solids sewage. Sorensen proposed the possibility for incorporating a saturation function in Gujer's model.

- C. Paper No. 6: "The Role of Filamentous Microorganisms in Activated Sludge Settling," by M. Sezgin (USA)

The author observed that the filament length concentration present in an activated sludge microbial culture had a pronounced effect on the settling characteristics of that sludge when the filament length concentration exceeded 10^7 $\mu\text{m/mL}$. The effect of filament length on the settling characteristics of a sludge were evaluated through measurements of reflocculation time, zone settling velocity and 60-min compact volume. Activated sludges from two laboratory units and twelve sewage treatment plants were utilized in the investigation. The general conclusions of the study were:

- a. No effect of filament length concentration on the settling characteristics of a sludge was observed when the filament length concentration was below 10^7 $\mu\text{m/mL}$.
- b. At high filament length levels, the zone settling velocity of a sludge decreased with increasing filament length.
- c. Increases in the sludge reflocculation time and the 60-min compact volume height were observed when the filament length concentration exceeded about 10^7 $\mu\text{m/mL}$.

In discussing the various forces acting on the biological floc particles during gravitational settling, the author advocates that filament interparticle forces are important at low levels of suspended solids concentration and the importance of these forces relative to floc interparticle forces decreases with increasing levels of suspended solids.

The official discussor of this paper was W. Pipes (USA). Pipes focused on the questions of validity, generality and applicability of the research results and conclusions. On the issue of validity, the discussor questions whether reflocculation time is a phenomenon which occurs in an activated sludge plant or whether it is an artifact of the measurement procedure of the zone settling velocity. Pipes also believes that all speculations as to the nature and role of interparticle and interfilament forces should be deferred until better techniques for the measurement of these forces are developed. On the subject of generality, Pipes states his amazement at the consistency of the data in spite of the fact that these data were collected from 12 sewage treatment plants and two laboratory activated sludge units. He indicated that there are more than thirty filamentous microorganisms which are recognized as being able to promote sludge bulking and he warned about the acceptance of Sezgin's

results as representing the general situation. As to the applicability of the results to the design and operation of activated sludge systems, Pipes stated that the results are interesting, however, their value to a sewage treatment plant operator is very limited.

Discussion from the floor centered mostly around the validity and applicability of the data. Jenkins (USA) felt that Sezgin's data interpretation went far beyond what is justified by the data available. In particular, Jenkins felt that due to the absence of any zone settling data for filament length concentrations below about $10^6 \mu\text{m/mL}$, Sezgin's proposed relationship was unjustified. On another matter, Jenkins warned that the complex arguments presented by Sezgin in support of the observations on the influence of filament length on settleability are not justified by the extent of his data and are an artifact of the plotting procedure employed.

Other floor discussers, Montalvo (Cuba), Grau (Czechoslovakia), and Matsche (Austria), emphasized the need for identifying the specific filamentous microorganisms present in the sludge and cautioned against generality because of the inherent differences in the growth rates and nutrient requirements of the various filamentous species that have been identified with sludge bulking. Another point of contention which was raised by Jenkins (USA) and expanded on by Esener (Netherlands) focused on the temperature of operation of the various plants reported on the study and the effects of variations in temperature on the settling characteristics of the sludge. Sezgin acknowledged the importance of the effects of temperature on settling parameters, however, he referred to literature information showing that the vast changes in settling characteristics due to filament length concentration far outweighed the effect of temperature.

- D. Paper No. 7: "Evaluation of Operational Benefits to the Activated Sludge Process Using Step Feed Control Strategies," by P. E. Sorensen (Denmark)

Two 16 m^3 aeration volume activated sludge pilot plants were operated in parallel at one of the municipal treatment plants in Copenhagen, Denmark. Each aeration tank consisted of three equal volume compartments connected in series and the objectives of the study were to investigate the controllability and the operational and economic advantages realized through automation. One of the two pilot plants was operated as a conventional step aeration plant

with the sewage strength equally distributed among the three aeration compartments while the other plant was automated. The control strategy, which was based upon maintaining a constant dissolved oxygen concentration in the third aeration tank, was accomplished through the use of a variable speed blower. The blower speed, on the other hand, was used to signal the strategy for the distribution of wastewater among the three compartments of the aeration tank.

The observations made from the experimental phase of the study revealed that process control would result in more uniform effluent quality, moderate savings in aeration related energy requirements, and a reduction in the excess sludge production rate. In addition, the step feed process offers the availability for sludge storage without needing an additional tank.

Mathematical simulations of the response of the treatment system to various control strategies revealed the following:

1. The oxygen transfer rate is a better control parameter than the organic loading rate because the food storage capacity of an activated sludge microbial culture leads to a smoothening out of the perturbations in oxygen demand.
2. A plug flow loading regime resulted in the lowest effluent BOD, whereas, the highest effluent perturbations and mean BOD concentrations were observed when the process was operated in the contact stabilization mode. Very uniform effluent quality was obtained when step feed strategies were employed.
3. Process control will result in the prevention of gross process failures due to temporary hydraulic overloads or sludge bulking.

Barnard (South Africa) was the official discussor. He emphasized the value of the step feed control system in alleviating process failure by hydraulic overloading of the final clarifier during wet weather flow. Barnard also stated that this mode of operation is utilized in South Africa in order to avoid wash-out conditions. The official discussor, however, failed to see any benefit of the step feed control system to the environment, especially when the author presented data indicating that the uncontrolled system produced better quality effluent than the controlled unit most of the time. Barnard warned of the danger of comparing the results obtained at the higher loading conditions with

those observed during normal operation since higher loadings were attained by supplementing the wastewater with glucose or the highly solubilized organic matter present in the supernatant from a sludge concentrator. Barnard also noted that the stability of the system observed at an F/M ratio of 0.2 is due to the low soluble BOD contribution and not to step feed control. Sorensen agreed with all these comments and added that the major value of the step feed control strategy is in the case where effluent discharge standards are relaxed during certain seasons of the year.

This paper stimulated vigorous discussion from the floor. Bhagat (USA) inquired whether the suspended solids in the effluents from the final clarifiers were measured. Sorensen indicated that the two clarifiers were oversized and that throughout the study the suspended solids concentration in the final effluents ranged between 15 and 30 mg/L. Jones (Canada) inquired about the ratio of particulate to soluble BOD present in the raw settled sewage since this ratio will determine whether contact stabilization or conventional activated sludge treatment will result in best performance. Sorensen, however, indicated that these data were not available. Jenkins (USA) suggested that the simulation model should incorporate sludge storage capabilities for the purpose of maintaining a constant F/M ratio. While acknowledging the need, Sorensen stated that a somewhat constant ratio was maintained since the sludge recycle rate was set as a fixed fraction of the raw sewage flow rate.

Molof (USA) informed the author of the availability of thirty years of data on the New York sewage treatment plant where step feed control is practiced and suggested that these data might be of assistance to the author in determining his optimal control strategy. Finally, in response to a question from Licklema (Netherlands) the author indicated that the value of the Michaelis Constant of 150 mg/L was adopted based on the author's doctoral research. The value of this constant was unimportant in this instance, since the substrate levels in the system were invariably low.

IV. CRITIQUE OF SESSION

Paper No. 4 focused on a very detailed and intricate model of the activated sludge process. The model represents a refined version of some of the presently used models, and it encompasses logical and thorough representations of many of the complex processes occurring within the biological treatment system. Paper No. 5 also represented a modeling effort on the role of organic particulate matter in the activated sludge process. This model offers a handy tool for

the distinction between the fate of dissolved and particulate matter in the activated sludge process and, in spite of limitations, the model represents a simple means for estimating certain of the design parameters for the process.

Paper No. 7 focused on the controllability and automation of the activated sludge process. An interesting conclusion from the paper is that the oxygen uptake rate provides a more reliable decision tool for process control than the organic or hydraulic loading rate on the aeration tank. Paper Nos. 4, 5 and 7 concentrated on the aeration phase of the activated sludge process while Paper No. 6 provided insight into some of the microbiological properties of activated sludge flocs that influence settling and thickening characteristics.

In summary, all four papers represent thorough attempts at the refinement of the integrated activated sludge wastewater treatment process. The intensity of discussions pointed to the strong interest of the profession in this process and emphasized the need for further research in order to better yet understand this very important biological treatment process.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The major significance of this session is to point towards the need for further research into the fundamental mechanisms of the activated sludge process. All four papers dealt with data derived from pilot- or full-scale activated sludge sewage treatment plants operating under transient and dynamic conditions. The excellence of the results indicated that we are at present knowledgeable enough about the process to venture into the fine modeling of real treatment systems and that the automation and control of biological treatment systems is within our grasp.

Three of the four papers in the session pertain to research conducted outside the United States. The fine quality of the work emphasizes the need for closer and more frequent association with the international community.

I. SESSION

A. Day: Tuesday, June 24, 1980
Hall: A
Time: 2:00 to 4:15 pm

B. Theme of Session: Biological Denitrification

II. REVIEWER

A. Name: Walter J. Weber, Jr.

B. Position and Affiliation: Professor of
Environmental and Water
Resources Engineering,
The University of
Michigan,
Ann Arbor, MI

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 8: "Industrial Waste Carbon Sources for
Biological Denitrification," by
H. D. Monteith, T. R. Bridle and
P. M. Sutton (Canada)

A project was conducted at the Wastewater Technology Centre, Burlington, Ontario, to evaluate industrial wastes or waste by-products which could be used as replacements for methanol as a carbon source in biological denitrification systems. Forty-one waste samples were analyzed to determine their organic carbon and nitrogen concentrations. Bench scale testing was done to determine batch denitrification rates for 30 of the wastewaters.

Twenty-seven of the industrial waste streams exhibited denitrification rates equal to or greater than methanol. Most wastes exhibited substrate consumption ratios between 0.7 and 2.6 kg of filterable organic carbon (FOC) per kg of $\text{NO}_3\text{-N}$ (nitrite plus nitrate nitrogen) removed, compared to the methanol average of 1.17 kg FOC/kg $\text{NO}_3\text{-N}$ removed. Substrate consumption ratio appears to be related to initial FOC:N ratio. Approximately 50% of the wastes tested had the required carbon content and were available in quantities sufficient to provide a constant supply of carbon for denitrification of domestic sewage and industrial wastes.

Where a denitrification treatment facility is adjacent to a waste carbon source, the concentration of the carbon is not a significant factor in its economic evaluation

as a methanol alternative. Under these conditions, savings of about 60¢/kg $\text{NO}_3\text{-N}$ removed can be realized, through utilization of the waste in lieu of methanol. Economic analysis revealed that only those wastes having a filterable COD greater than 60,000 mg/L can be considered as economically feasible methanol alternatives for a transportation distance of 110 km.

The formal discussion by Sekikawa (Japan) covered three-stage denitrification plant experiences in 1969. He indicated carbon sources containing multiple organic compounds require significant acclimation periods and produce different types of sludges. He suggested that it is necessary to consider potential toxicity effects of wastes, particularly chronic toxicity, and noted that industrial wastes may also contain nondegradable organic compounds which will increase COD levels.

The author agreed on the issue of acclimation and cited economic and time limitations of the study as factors which prohibited more detailed evaluation of this question. The author also agreed that chronic toxicity tests are necessary, and suggested desirability of long term continuous-flow reactor tests rather than short term batch tests used in the present study.

In floor discussion Bhagat (USA) expressed concern with respect to higher COD levels in effluents. The author replied that the reactors were not carbon limited and effluent COD levels were in fact higher. Grau (Czechoslovakia) addressed the issue of soluble COD removed and asked if the authors had evaluated this with respect to the NO_2 and NO_3 reduced. The author replied that such ratios had not been determined and acknowledged that this would be desirable in future work.

Barnard (South Africa) asked if carbon already present in the original waste was used prior (preferentially) to that in the added industrial wastes and briefly described an experience in which a synthetic fuel plant waste high in phenols and ammonia was successfully nitrified and then denitrified by combining with another waste which contained high concentrations of fatty acids. The author replied that the original wastes were carbon limited, and he did not think minor amounts of carbon remaining in these were used preferentially.

Chen (USA) asked if phenol could serve as the carbon source. The author indicated that he did not know. Pal (Kuwait) asked what the authors would recommend with respect to a choice between oil and urea as potential carbon sources for denitrification, and whether there was a limit on ammonia

concentrations which can be "treated". Monteith indicated he could not reply to these questions. Sutton (a co-author) commented that much previous work had been done on ammonia inhibition of nitrification, but not denitrification. He further noted with respect to Barnard's comment that advantage can be taken of carbon in raw sewage in some circumstances, but it was often found that this was not enough to allow reaction to proceed under non-carbon-limited conditions, in which case slower endogenous denitrification occurs.

Wheatland (UK) asked how the authors insured that they were comparing rates under the same conditions of excess carbonaceous substrate. Monteith replied that they attempted to add all industrial wastes in amounts required to give the same C:N ratios in all cases, and to maintain MLVSS in the range of 2,000-5,000 mg/L in all reactors.

Suidan (USA) indicated that all tests were conducted with high carbon concentrations and that methanol might be more readily available than complex industrial waste organic compounds at lower concentrations more typical of practice. The author agreed and acknowledged the need for verification of such issues in long term continuous-flow tests.

- B. Paper No. 9: "Kinetic Model of Biological Denitrification in a Fluidized Bed Biofilm Reactor (FBBR)," by L. T. Mulcahy, W. K. Shieh and E. J. LaMotta (USA)

A kinetic model for denitrification processes in fluidized-bed attached-growth reactors was described, and comparisons were made between model predictions and experimental data from a laboratory-scale reactor. The author concluded that: (1) Intra-biofilm diffusion of nitrate limits denitrification in a FBBR when the modified Thiele modulus is greater than 1.15, (2) Diffusion-limited FBBR denitrification results in nitrate profiles exhibiting 0.55 order kinetics (or 0.45 order kinetics for denitrification rate) in the FBBR, (3) FBBR denitrification rate will be diffusion limited for nitrate levels normally present in nitrified municipal wastewaters, and (4) The model is capable of predicting FBBR denitrification performance with reasonable accuracy and is thus a rational basis for system design.

In formal discussion by Elmaleh (France), the validity was questioned of each of the two assumptions that (i) biomass was constant, and (ii) no clarification was required. He would like to have seen data on biomass in the reactor effluent and questioned the assumption of uniform

coverage of reactor media with biomass and asked at which point in the bed the profiles were determined. He asked to what extent external resistances to mass transport might affect validity of model predictions and noted that the Theile modulus (modified) was introduced in a first-order context, and asked what are the extreme criteria of this modulus for initial coverage. He questioned both the validity of using the particle radius as a characteristic dimension rather than the thickness of the active biofilm and the sensitivity of the model to changing parameters in that the profiles obtained differed very little for remarkably different circumstances.

In response Mulcahy indicated he did not think the FBBR would come to steady-state by attrition loss of biomass; rather that the media would simply continue to expand, requiring periodic scour. He expressed feeling that no clarification was therefore necessary. The author stated that there was very little biofilm on media near the bottom of the reactor while those near the top were like "clunkers." He therefore limited his analysis of profiles to the middle section of the FBBR only. Additionally, the author commented that they were not "trying to duplicate Aris' work," stated that they used particle radius because Aris had done so, discounted external diffusion resistances, and estimated an error of only 5-7% associated with the latter assumption.

In floor discussion Silveston (Canada) indicated that he also questioned several assumptions of the model, particularly that of pseudo-steady-state operation in view of the authors' acknowledgement that the biofilm was continuously growing. He further noted that the Theile modulus was not constant, but did not appear to be included in the integration of the model equations. Silveston questioned zero-order assumptions and asked whether nitrate or methanol flux was limiting. Mulcahy expressed feeling that pseudo-steady-state assumption was "useful," and that "equilibrium" thickness of the biofilm could be obtained by controlling operational parameters. He indicated that a 6:1 methanol to nitrate ratio was used, so that methanol flux should not have been limiting.

Suidan (USA) commented that the Theile modulus should be independent of concentration for zero-order kinetics. Harremoës (Denmark) noted that the authors' model did not account for the effects of bubble formation and release in the column as a result of denitrification.

- C. Paper No. 10: "Kinetics of Biological Fluidized Bed Wastewater Denitrification," by J. P. Stephenson and K. L. Murphy (Canada)

Experiments were conducted to describe the kinetic performance of a pilot scale biological fluidized bed reactor for municipal wastewater denitrification. A half-order kinetic model coupled with an Arrhenius temperature dependence relationship was employed. The authors concluded that: (1) an Arrhenius-type temperature dependency is exhibited for denitrification; the fluidized bed process appears less temperature sensitive than suspended growth or RBC processes, (2) a half-order model appears adequate to describe denitrification kinetics, (3) hydraulic feed rate and media type (granular carbon and sand) did not have significant effects on denitrification rate, and (4) for equal treatment capability, the fluidized bed denitrification process requires a hydraulic retention time almost one order of magnitude less than a suspended growth or RBC reactor.

In formal discussion Irvine (USA) asked how much methanol was added, whether effluent was clear, and what effluent concentration of ammonia was obtained.

He also inquired about costs of the process, suggested that staging of reactors might be considered, and asked which features of the process were most amenable to control.

The author responded that methanol was initially added in stoichiometric amounts, but that most of the work was done with a methanol level of three times the stoichiometric requirement. He further indicated that effluent was sometimes clear, but otherwise either cloudy or very turbid, that effluent ammonia concentrations were generally less than 1-1.5 ppm, and that control of solids growth in the reactor and of wash-out of solids in the effluent was required.

In floor discussion W. J. Weber, Jr. (USA) questioned the generality of the conclusion that there is no difference between granular carbon and sand as support media in that the experiments were conducted only under conditions in which the organic carbon (methanol) was neither limiting nor strongly adsorbable. When other carbon sources are used and/or the organic carbon levels are closer to limiting conditions, the adsorptive concentrating effect of the activated carbon may offer some advantages.

Rittman (USA) questioned the conclusion of 0.5-order reaction kinetics in view of the high degree of scatter observed in the experimental data. He asked whether there are other data to support this conclusion. Stephenson acknowledged scatter of data, but indicated that he has other data to support conclusion of 0.5-order kinetics.

Earle (New Zealand) asked whether the principal difference between fluidized-bed reactors and suspended-growth reactors was not simply the higher density of volatile suspended solids in the former.

Harremoes (Denmark) suggested the use of larger particles to obtain higher efficiencies. Stephenson disagreed, and indicated smaller particles should give higher efficiencies.

Silveston (Canada) expressed concern that the observed variation in the Arrhenius pre-exponential factor with flow rate seemed to suggest an inadequacy in the model.

IV. CRITIQUE OF SESSION

There was substantial international interest in biological denitrification processes. The issues and needs addressed by the papers appear timely. Particular items of interest were those relating to use of concentrated industrial wastes to provide for organic carbon requirements, and the potential advantages of the fluidized bed over dispersed growth processes. While the notion of using industrial organic carbon sources was generally viewed as attractive, there was a good deal of concern expressed regarding the fact that potentially deleterious side effects — such as toxicity and high effluent COD levels — were not adequately addressed in the work presented. With respect to the fluidized-bed process, there appeared to be a general feeling that the modeling efforts described in the papers were somewhat oversimplified, and might be erroneously applied if all of the limiting assumptions used therein are not fully recognized. Several individual comments after the session indicated that a number of participants would have been more interested in seeing the results of side-by-side operating comparisons of fluidized beds with dispersed-growth reactors, and in seeing more hard data to support some of the claims made in the papers for the potential advantages of FBBR's.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The three papers in this session described work done in either Canada or the U.S. The elimination of all nitrogen species from waste discharges appears to have had more emphasis in U.S. and Canadian water pollution control legislation and general concern than it has had in most other countries. This is most likely an issue of timing and state-of-art practice, for denitrification first requires prior biological treatment to a degree sufficient to accomplish nitrification of reduced forms of nitrogen. The

information presented in this session — subject to some of the caveats mentioned in the preceding section of this report — appear therefore to have direct and significant bearing on U.S. research activities. The papers and the discussion relating thereto have particular value in defining more clearly those aspects of biological denitrification processes which require further research efforts.

I. SESSION

- A. Day: Wednesday, June 25, 1980
Hall: A
Time: 9:00 am to 12:30 pm
- B. Theme of Session: Innovative Biological Treatment Processes

II. REVIEWER

- A. Name: Leo T. Mulcahy
- B. Position and Affiliation: Assistant Technical Director
Westvaco Corporation
Covington, VA

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 11: "Denitrification of Water for Human Consumption," by Y. Richard, A. Leprince, G. Martin and C. Leblanc (France)

The authors presented experimental results and a mathematical model describing potable water denitrification in a biological fluidized bed. A compound Monod-type kinetic expression was developed to describe the dependence of observed reaction rate on nitrate, phosphate and organic carbon concentrations. High raw water nitrate levels (90-150 mg/L) and the addition of stoichiometric quantities of carbon (as ethanol or acetic acid) were cited in simplifying this expression to one dependent only on phosphate concentration. A Lineweaver-Burk plot analysis was used to quantify this phosphate concentration dependence, with the resultant maximum rate and half-velocity constants being 250 mg $\text{NO}_3/\text{hr} \cdot \text{gVSS}$ and 0.34 mg $\text{PO}_4^{3-}/\text{L}$, respectively.

A further simplification was justified on the basis of constant phosphate feed concentration to yield a final rate expression which is zero order in N, P and C.

A reactor model was then developed which linked nitrate removal rate to expanded bed height and superficial velocity. Expanded bed height was, in turn, correlated to superficial velocity, unexpanded bed height and the "particles' degree of coating."

Points raised by Sekigawa (Japan) in his prepared discussion included the following:

- Use of a biological step in potable water treatment may result in bacterial contamination of the product water.
- Electron donor compounds added for biological denitrification may increase the product water TOC.
- Reactor seeding is accelerated by the use of a tapered column inlet structure.
- Bulky growth can be minimized through use of relatively large support media; 0.6 mm sand was found satisfactory.

The discussor noted that in similar work he was able to achieve approximately 100 mg VSS/g sand which is roughly three times the maximum concentration reported by the authors. He also noted that the authors report a uniform VSS distribution while he observed a nonuniformity which increased with column diameter.

In open discussion, Mulcahy (USA) noted that his experience, the literature and the authors' own data all suggest that fluidized bed expansion is better described by an exponential function than the arithmetic relationship used by the authors. It was also observed that in developing their bed model the authors implied the relationship $U = U/\theta$ (at $\theta = 1$) where U is superficial velocity and θ is bed porosity. It was stated that this is counter to observed fluidized bed behavior since bed porosity increases with increased superficial velocity.

Harremoes (Denmark) noted that the authors' rate analysis was unusual and interesting in that rate was determined as a function of feed rather than local phosphate concentration, yet a reasonable approximation of Monod-type kinetics was observed. He also expressed surprise at the linear relationship between observed rate and volatile solids concentration presented by the authors. He expected the rate to decrease at higher VSS levels due to intrabiofilm diffusional limitations.

Another discussor commented that in Germany autotrophic bacteria are used for potable water denitrification. This eliminates the possibility of organic contamination by the added electron donor. He also asked if nitrite production had been observed by the authors.

Henry (Australia) pointed out that the European Economic Community is developing new drinking water standards which include nitrate limits much lower than the current 50 mg/L cited by the authors. The presenter was asked to comment on the ability of their process to comply with these new standards.

Sutton (USA) said that the uniform VSS concentration observed by the authors was contrary to his experience. He asked for details of their solids sampling device.

The author replied that biological denitrification of a potable water does entail a number of problems. It is necessary that biological denitrification be integrated into a complete treatment chain which includes post aeration, filtration and disinfection. The authors observed no nitrite residual under stable reactor operation. They believe that their process can, with possible slight modification, meet the stricter future EEC nitrate standards. Solids were sampled by a simple pipetting procedure. The presenter noted that bed homogeneity decreased as time between washings (for solids control) increased.

- B. Paper No. 12: "Biological Nitrogen Removal by Step-Feed Process," by Y. Miyaji, M. Iwasaki and Y. Sekigawa (Japan)

Advantages of a multi-stage step-feed single sludge nitrogen removal process were discussed. Single sludge nitrification-denitrification systems are attractive because they require minimal addition of organic carbon and alkali. Conventional single sludge systems do, however, require extensive recycle of nitrification tank mixed liquor to achieve reasonably low effluent nitrogen levels.

The process described by the authors utilizes a series of denitrification-nitrification stages with influent equally split (step-feed) among each of the denitrification tanks. This is presented as a means to minimize and possibly eliminate recycle of nitrification tank mixed liquor. The relationship among nitrogen removal rate, recycle ratio and the number of stages was developed from a nitrogen mass balance. For example, 80% nitrogen removal required a 4:1 recycle ratio for a single-stage system, 1.5:1 for a two-stage system and less than 0.5:1 for a four-stage system. Theoretically, recycle can be eliminated completely by increasing the number of stages used, provided the denitrification reaction is not limited by the organic carbon supply.

Relationships were developed between operating costs and the number of denitrification-nitrification stages used. The costs associated with aeration power, recirculation power and chemical addition (NaOH and CH₃OH) were considered. Again using 80% nitrogen removal as an example, the single-stage system required 20% more power than a two-stage system and 40% more power than a four-stage system.

An overall operating cost analysis for a four-stage step-feed process showed a sharp increase in recycle pumping costs for nitrogen removals above 95%. Thus for a four-stage system in which greater than 95% removal is required, it was concluded that costs are minimized by a two-pronged approach which achieves 95% removal through adjustment of recycle rate and the remaining few percent through use of a final, methanol-fed, denitrification tank.

Operating data from a 75 m³/day four-stage step-feed plant treating night-soil agreed well with values calculated by the derived mass balance relationship. Approximately 93% nitrogen removal was obtained without methanol addition while values in excess of 99% were obtained when methanol was added to a final denitrification stage.

Andrews (USA), the appointed discussor, commented that this application of the reactors-in-series concept is attractive because it avoids the creation of high nitrate concentrations in any one reactor which might depress pH and lead to nitric acid production. He noted that the authors distributed inflow equally among the denitrification tanks and asked if this were the optimum. He also asked if the authors had considered changing wastewater addition points as a means of effecting real time control of the process. It was observed that the major operating cost component for nitrogen removals under 95% was for NaOH. Therefore influent alkalinity has a strong effect on cost in this operating range. Andrews noted that alkalinity measurements can be affected by short chain fatty acids which were likely present in the night-soil influent. Finally, the discussor criticized the rigor of the authors' neutralization equation suggesting that it should have been derived from fundamental principles.

In open discussion, Barnard (South Africa) stated that the authors' cost comparison between single and multi-stage nitrogen removal systems was wrong because of their misconception about mixed liquor recycle pumping costs. In more than 20 single-stage (i.e., a single denitrification tank followed by a single nitrification tank) plants in operation in South Africa, Barnard noted that only the normal pumping capacity of the surface aerators is used to recycle

mixed liquor. In a diffused air plant built for the city of Johannesburg (service population 750,000) it was noted that only ten KW are required for axial flow mixed liquor recycle pumps. On these bases, Barnard concluded that mixed liquor recycle pumping costs are insignificant.

He also commented that a plant in Capetown achieves 97% nitrogen removal in a single tank by on-off operation of their aerators. Barnard observed that the Capetown plant is doing in time what the authors' process accomplishes in space.

Sutton (USA) questioned the system's ability to maintain a nitrifying population at the design SRT of 7.7 days (only 3.85 days in nitrification) at the minimum 15°C temperature.

The authors replied that equal distribution of inflow was used to attain a uniform carbon to nitrogen ratio which the authors believed to be the optimum. The presenter thanked Barnard for his informative comments. It was noted that although the design SRT was 7.7 days, the system was actually operated at a SRT of 20.7 days which was adequate for nitrification. The author commented that although nitrogen removal rate increases with the number of stages used, economics limits practical design to, at most, three or four stages.

- C. Paper No. 13: "Continuous Bioregeneration of Granular Activated Carbon During the Anaerobic Degradation of Catechol," by M. T. Suidan, W. H. Cross and M. Fong (USA)

The authors presented the results of an extensive study (490 days) on anaerobic biological activity within granular activated carbon (GAC) adsorbers treating a synthetic catechol wastewater. Advantages claimed for the anaerobic GAC filter include: (1) extended bed life due to continuous bioregeneration of the carbon; (2) retention of refractory organics for biological acclimation and degradation; and (3) provision by the GAC of a nutrient reservoir which adsorbs substrate during periods of high organic loading for release and biological degradation when substrate concentration subsides.

During the initial 320 days of experimentation, catechol feed to the series of four pilot columns was held constant at 200 mg/L. Three successive stages of system performance were observed. During the first (<120 days), little biological activity was in evidence (i.e., no gas

production) and all catechol reduction was attributed to adsorption onto the GAC surface. It was said that this adsorption rendered the substrate unavailable for microbial degradation. The second stage (120-235 days) was one of active gas production indicating vigorous biological activity. Total aqueous and gaseous carbon (TAGC) from the first column was observed to exceed total carbon in the feed. This was attributed to bioregeneration of the activated carbon in that column. In the third stage (235-321 days), effluent TAGC was approximately constant at 91% of the feed carbon concentration and the system was said to have reached steady-state. During steady-state operation, the bulk of the removal load was carried by the first column (contact time 11.62 hr) which achieved reductions of up to 81% TOC, 88% COD and greater than 99% catechol. It was noted that the gaseous product was an almost CO₂-free methane gas. This was attributed to the relatively low strength organic feed, low detention time and high CO₂ solubility at neutral pH.

Additional experimentation was conducted into the effects of increased catechol feed concentrations on system performance. An increase from 200 to 400 mg/L (Day 321) resulted in a shift to new steady-state conditions with increased gas production. The first column again accounted for the bulk of the removal with reductions of 86% TOC, 86% COD, and greater than 99% catechol.

A final increase to 1000 mg/L catechol feed (Day 460) again resulted in increased gas production. Only 51% of the feed carbon was accounted for in the effluent. This was cited as proof that the GAC retained residual adsorptive capacity.

The authors conclude that the anaerobic GAC filter was demonstrated to be an effective process for the degradation of catechol (> 99%) as well as for the removal of TOC (81%) and COD (95%). In addition, a methane-rich by-product gas is produced. The attainment of steady-state conditions was said to indicate continuous bioregeneration of the carbon surface. This implies a process in which the costly carbon regeneration step could be eliminated.

Weber's (USA) formal discussion focused on whether the authors' claims of continuous bioregeneration, process effectiveness and energy efficiency were justified by the data presented in their paper. He noted that the claim of bioregeneration is based on the observations that: (a) discharge carbon can at times exceed feed carbon, and (b) steady-state operation of the columns can be achieved. He

further noted that both of these phenomena are common to any biofilm reactor and are, therefore, not sufficient proof of bioregeneration.

With regard to process effectiveness, it was pointed out that the anaerobic contact time of 11.62 hours is more than an order of magnitude greater than that required for either straight adsorption or aerobic biologically assisted operation. No capacity advantage was anticipated versus the aerobically active column. Weber further noted that no energy balance calculations were given and therefore the author's claim of energy efficiency is unfounded.

Benedek (Canada) in open discussion asked the presenter to comment on the advantages of activated carbon over media which might be used to support biofilm; sand, for example.

Azkona (Spain) commented that application of the authors' process would be limited since he believed catechol was the only aromatic which would degrade anaerobically.

Pal (Kuwait) suggested that radioactive labelling be used to settle the bioregeneration controversy.

Mulcahy (USA) commented on Weber's discussion by noting that although process kinetics favor aerobic biological activity, very real advantages can be realized with anaerobic operation since sludge production is minimal.

In reply, the author stated that the 11.62-hr empty bed contact time was not determined through process optimization and could possibly be lowered. The author noted that his system ran for more than three years without carbon attrition or the need to regenerate. These were said to be important cost factors which must be considered in comparing the authors' process to a straight adsorption system. The author observed that phenol is also readily degraded in an anaerobic GAC bed. Activated carbon was said to be a superior media for such applications for two reasons: (1) it provides a nutrient rich surface to which biofilm readily attaches; and (2) it provides adsorptive capacity which can dampen organic concentration spikes. The author indicated that developmental work is currently underway to evaluate the performance of the process in treating strong phenolic wastewaters, coking liquors and a glycol-fluorocarbon fire retardant wastewater.

D. Paper No. 14: "Bayer Tower Biology - An Efficient, Low Noise and Odor-Free Process for Biological Wastewater Treatment," by E. Schellmann (W. Germany)

This paper concerned a two-stage wastewater treatment plant under construction for Bayer AG, Leverkusen, West Germany. The first stage, which is to be fed 90,000 m³/day industrial wastewater, utilizes four deep cylindrical steel tanks (30 m height, 26 m diameter) as aeration basins. This configuration was chosen because of space, noise and odor constraints tied to the plant's location in a crowded residential area. Clarified first-stage effluent will then be combined with 70,000 m³/day municipal wastewater and fed to a second-stage conventional large-area aeration basin with clarifier. The first stage deep tank design was made practical by Bayer's development of a novel slot-injector, claimed to produce a fine dispersion of air bubbles with relatively low power consumption (3 kg O₂/kWh).

It was claimed that deep tank design lessens noise problems in two ways. First, less air compression is required due to increased oxygen transfer efficiency. Second, the compressors can be located in a single structure which is easier to insulate than individual surface aerators.

Deep tank design was claimed to lessen odor problems by allowing for reasonably cost effective incineration of tank off-gases. It was estimated that by increasing tank depth from 5 to 26 m, off-gas production would be cut by two-thirds. Another factor which improved the practicality of off-gas incineration was the development of a UV catalyzed incinerator which was claimed to operate stably at 750°C with 4 volume percent oxygen feed. Energy savings of 50% were claimed in comparison to conventional incinerators.

It was noted that although a 17 m tank depth minimizes oxygen transfer efficiency for slot-injectors, overall operating costs are minimized when a tank depth of 26 m is used. This is due to the fact that incineration cost, a major component of overall cost, decreases sharply with increased tank depth (i.e., decreased off-gas volume) while aeration cost increases gradually with tank depth beyond 17 m.

In addition to Leverkusen, two other West German industrial plants, a petrochemical complex and a brewery, have under construction wastewater treatment units employing the Bayer deep tank process.

In his prepared discussion, Rincke (W. Germany) questioned the data base for design of the Leverkusen plant. He wanted to know if the system design is sufficiently flexible to allow process adjustment as operating experience is accumulated. He also asked the author to compare the Bayer process to more conventional biological treatment systems. Finally, he asked if the use of high purity oxygen had been considered by Bayer for their deep tank system.

Jansen (Netherlands), in open discussion, asked what BOD and TOC removal efficiencies can be expected from the Bayer deep tank process; what pretreatment steps are required; how significant is stripping and incineration of refractory organics?

Kolbe (South Africa) noted that two-stage biological processes produce relatively large quantities of sludge. He asked what sludge production could be expected with the author's process.

The author noted that design of the slot-injector system was based on Bayer's extensive chemical processing experience with injector systems as well as an extensive pilot testing program. He replied that the process has considerable flexibility since air and liquid flow through the injector system can be varied independently. Bayer is considering a feed-back control loop to adjust injector operation. The author stated that the deep tank design is most attractive for treatment plants which require an off-gas incineration system; otherwise, capital would be tough to justify. It was noted that oxygen systems are only attractive if a use can be found for the by-product nitrogen. The author stated that BOD removal efficiencies in excess of 95% are expected. Pretreatment steps to be used at Leverkusen are neutralization and primary settling. The author replied that the effect of stripping and incineration on the system carbon balance had not been quantified. Schellmann indicated that waste sludge will be fed to a Porteous reactor (220°C, 2 hr) and subsequently filtered to 50% solids for landfill disposal. Anaerobic digestion is being considered but the presence of heavy metals in the sludge presents problems.

IV. CRITIQUE OF SESSION

Paper No. 11 addresses application of biological fluidized bed technology to nitrogen removal from a high nitrate drinking water supply. The mechanistic analysis of the authors seems of limited value. The process was, however,

shown capable of high nitrate reductions. The discussers highlighted problems related to application of biological denitrification to potable water treatment, namely, the need to deal with bacterial and organic (added electron donor) contamination of the product water. As noted by the author in his reply, biological denitrification would have to be integrated into a rather complex process capable of dealing with these added contaminants.

Paper No. 12 applies the tanks-in-series concept to biological nitrogen removal. Significantly lower mixed liquor recycle costs were cited by the authors as a major advantage of their process. Barnard, however, noted that the authors were wrong in this part of their analysis and that recycle costs were, in fact, insignificant. The authors' process does offer significant advantages such as step-wise nitrification which results in decreased alkali costs and improved reaction kinetics.

Paper No. 13 presents a process with broad applicability to treatment of industrial wastewaters. The system is in essence an anaerobic biological reactor with the added advantage of adsorptive removal. This adsorptive capacity is especially useful during startup or periods of organic surges. It is also useful in retaining poorly biodegraded substances for biological acclimation and subsequent degradation. Although an aerobic biological reactor with activated carbon support media has these same advantages and requires less contact time, the anaerobic process minimizes problems related to biofilm buildup and sludge handling.

Paper No. 14 presents an interesting approach to wastewater treatment in applications where off-gas treatment is required. By using a deep tank with novel slot-injectors for aeration, off-gas volumes are substantially reduced and overall costs including off-gas incineration minimized. The author focused attention on the slot-injector and gave a very superficial treatment to the biological process itself with no mention of removal efficiency and sludge production.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Potable water denitrification is a topic of interest in several areas of the U.S. including the southwestern states and Long Island, NY. The biological denitrification approach advanced by the authors of Paper No. 11, although efficient, produces a water with increased bacterial levels and possibly organic contamination. A combination of

biological denitrification and processes to remove the resulting contaminants may, however, be economically attractive compared to existing chemical and physical nitrate removal schemes which are relatively expensive. Research into a comprehensive system including biological denitrification and required ancillary processes is needed.

Nitrogen removal from wastewaters is of general interest in the U.S. The step-feed process presented in Paper No. 12 appears to offer advantages over conventional single-sludge nitrification-denitrification systems. Optimization of influent division to the unit is an area requiring further research.

The anaerobic biological process presented in Paper No. 13 is timely because of its potential for converting waste organics to a useful by-product, methane gas. As noted by Weber, side-by-side testing of the anaerobic biologically active GAC bed with an aerobically active GAC bed and a straight (not biologically active) GAC adsorber would allow a more definitive comparison of these processes.

Bayer has shown that engineering talent and capital can be used to create a space-efficient industrial wastewater treatment plant capable of odor-free, quiet operation in a crowded residential area. The deep-tank design, slot-injection aerators and energy efficient off-gas incineration all merit consideration by U.S. designers.

I. SESSION

A. Day: Wednesday, June 25, 1980
Hall: A
Time: 2:00 to 4:15 pm

B. Theme of Session: Biofilm Models and Processes

II. REVIEWER

A. Name: David Jenkins

B. Position and Affiliation: Professor of Sanitary
Engineering,
Director, Sanitary
Engineering Research
Laboratory,
University of California,
Berkeley, CA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 15: "Nitrification Kinetics in a Rotating
Biological Disk Reactor," by
Y. Watanabe, M. Ishiguro and K.
Nishidome (Japan)

The paper described the development and testing of a kinetic model of nitrification in rotating biological contactors (RBC). The variables tested were temperature, disc rotational velocity, partial pressure of oxygen in the gas phase, hydraulic loading and influent ammonia concentration. The basis of the model is a simultaneous molecular diffusion of ammonia and a zero-order ammonia oxidation (nitrification) rate in the biofilm; liquid diffusion resistance external to the biofilm is neglected. The model predicts, and the authors results support, a bulk first order reaction with respect to ammonia concentration at extremely low (~5-10 mg NH₃-N/L) ammonia concentrations followed by half-order and then zero order reactions with respect to ammonia concentration as the ammonia concentration progressively increases.

The invited discussor was Margaritis (Canada); contributors to the floor discussion were Harremoës (Denmark), Rittman (USA), and Strand (USA). The points raised by their discussions are combined below.

Some question was cast on the depth of model verification because the author indicated that the data in Figs. 4-20 of the paper were all derived from single experiments; no estimate of standard deviation or of goodness of fit was available because there was no replication of any of the experiments. The selection of rate constants for the nitrifying bacteria seemed to be somewhat arbitrary since they were derived by subjecting experimental nitrification rate data to a biofilm coefficient; moreover it was assumed that the nitrification rate coefficients for suspended and attached nitrifying bacteria were the same at 30°C; no temperature optimum was indicated for either form of nitrifying bacteria.

Harremoes raised two very important points. By replotting the author's data he showed that the RBC units became oxygen limited at bulk ammonia nitrogen concentrations of approximately 10mg $\text{NH}_3\text{-N/L}$. He also showed that at greater than 10mg $\text{NH}_3\text{-N/L}$ in the bulk solution the zero order nitrification rates (with respect to $\text{NH}_3\text{-N}$ concentration) were 1/2 order with respect to bulk partial pressure of oxygen. Rittman verified this transition from first order at low $\text{NH}_3\text{-N}$ bulk concentrations to zero order at higher bulk levels of $\text{NH}_3\text{-N}$, however he emphasized that the change in reaction order was not sharp but rather a gradual transition in reaction order occurred. Furthermore Harremoes pointed out that there was a deviation of the nitrification rates from zero order with respect to $\text{NH}_3\text{-N}$ concentration at high bulk $\text{NH}_3\text{-N}$ levels and suggested that this was a consequence of the author's neglect of external diffusion resistance in the bulk solution. This latter point was reiterated by Rittman whose experience had led him to the conclusion that external mass transfer resistance could not always be neglected. In response to these lines of discussion, that indicated oxygen limitation in the biofilm at bulk concentrations of ammonia in excess of 5-10 mg $\text{NH}_3\text{-N/L}$, the authors promised to present the results of calculations using a 2-phase diffusion model (considering both $\text{NH}_3\text{-N}$ and oxygen) in the published proceedings (J. Water Technol.) of the Conference.

Further to the question of oxygen limitations in the biofilm the problem of measuring active biofilm depth was raised. Watanabe indicated that he could calculate active biofilm depth on two bases - aerobic depth from the DO profile and nitrification depth from his nitrification rate data. These two methods gave good agreement - 60um for the former and 75um for the latter.

- B. Paper No. 16: "Practical Problems Related to Nitrogen Bubble Formation in Fixed Film Reactors," by P. Harremoes, J. La C. Jansen and G. H. Kristensen (Denmark)

This excellent paper addressed one problem associated with the outdiffusion and outtransport of products of biological reactions in biofilms — that of the removal of nitrogen generated by the denitrification reaction. Harremoes' motive for working on this problem was to reconcile some of the highly variable denitrification rates reported in the literature for fixed bed, fixed film reactors. Supersaturation of the aqueous phase with $N_2(g)$ is predicted to occur and to generate $N_2(g)$ bubble build-up in the biofilm when more than 6 mg NO_3-N/L is denitrified. Depending on the type of biofilm reactor utilized a variety of things may occur as the result of $N_2(g)$ supersaturation. In fixed bed, fine media, fixed film reactors the $N_2(g)$ bubbles enlarge to the point where they rupture the biofilm which, if the flow is rapid enough, may become completely detached leaving a bare spot in the biofilm. Denitrification rates will decrease because of the loss of biofilm and the presence of bare spots. In less turbulent floc conditions the ruptured biofilm may stay attached and flutter in the bulk fluid flow; regrowth of the bare spot left by the ruptured biofilm will occur to produce a thicker biofilm. Consequently denitrification rates will increase because of the presence of a greater amount of biomass per unit area of biofilm. Further, the presence of $N_2(g)$ bubbles within a biofilm will decrease denitrification rate by preventing bulk liquid from reaching parts of the biofilm.

Harremoes showed evidence of nitrogen bubble formation in slides of laboratory biofilms. He concluded from this work that fixed bed fine media columns or upflow fixed bed columns should not be employed for denitrification because of the deleterious effects of $N_2(g)$ bubble accumulation on denitrification rates.

In additional comments Professor Harremoes addressed another issue involving the outdiffusion of products of a biochemical reaction within a biofilm. Denitrification consumes strong acid or conversely produces strong base (OH^-). The production of this strong base within the biofilm elevates the pH at the interior of the biofilm. Harremoes showed slides of sections through denitrifying biofilms where the pH elevation at the rear of the biofilm had proceeded to the point where chemical precipitates (presumably of calcium carbonate and calcium phosphate) had

formed. The occurrence of such precipitates provides one possible explanation for the so-called "luxury biological uptake" of phosphate in some activated sludge plants employing anaerobic and anoxic zones for denitrification.

The invited discussion was by Sutton (USA); other discussion was by Silverston (Canada), Murphy (Canada), Gujer (Switzerland) and Trout (New Zealand).

Sutton agreed that fixed bed upflow and downflow columns were less efficient and produced more variable results in denitrification than did fluidized beds. He suggested, and Harremoes agreed, that future denitrification research should be directed towards fluidized bed systems where $N_2(g)$ bubble accumulation and rupturing of film is prevented by the turbulence in the medium effectively preventing formation of large $N_2(g)$ bubbles by removing the tiny $N_2(g)$ bubbles as soon as they form. Also such systems allow operation to control biofilm thickness. Harremoes indicated that his group was now working on fluidized bed denitrification using systems without sand. The systems are similar to the upflow fluidized beds used by the Dutch where very dense sludge is formed through which the bulk material flows. A further disadvantage of upflow beds with low velocities was that occasionally the $N_2(g)$ bubbles might cause the media to be so bouyant that it will float and be washed out of the column. Murphy related such an experience.

Extending these experiences to RBC systems it was noted that fully submerged RBC units for denitrification develop a thick film (or matt) that bridges the space between the biodisc surfaces. This heavy film growth is possible because the low shear values present in fully submerged RBC units do not strip away biofilm ruptured by N_2 bubbles. Thus the biofilm continues to accumulate and eventually spans the biodisc surfaces in a thick matt.

Harremoes agreed that the problems he associated with gas bubble prediction in biofilm reactors would be less in anaerobic reactors than in anoxic (denitrifying) systems because of the smaller amount of growth in anaerobic systems.

Some questions were raised concerning the values of diffusion coefficients for NO_3^- and N_2 used in the paper. Dr. Harremoes used literature values that had been determined under conditions he thought were closest to those of his experiments. Gujer asked what degree of supersaturation of $N_2(g)$ in water was required to obtain an $N_2(g)$ bubble under the experimental conditions - no answer was forthcoming.

Trout indicated that back diffusion of reactants (e.g., CO_2 in the production of ethanol) had been recognized as a limiting factor in the fermentation industry for many years.

C. Paper No. 17: "Design of Fixed-Film Processes With Steady-State Biofilm Model," by B. E. Rittman and P. L. McCarty (USA)

Rittman presented a biofilm model that incorporated substrate utilization in the biofilm, substrate transport to the biofilm and growth kinetics in the biofilm. The unique feature of the biofilm model was that a steady-state assumption is made for growth so that the growth of the organisms in the biofilm is just balanced by their decay. The model was tested by application to four situations of significance to water pollution control - fluidized bed denitrification using methanol as carbon source, methane production from an acetic acid propionic acid mixture, groundwater recharge with a tertiary wastewater effluent and RBC treatment of a high strength waste using an O_2 atmosphere.

The author claimed a good fit of the model to the data from these sources but the discussers (Reynolds, USA; Shie, USA; Harremoes, Denmark; Shelef, Israel; Grady, USA; and Mulcahey, USA) cast some serious doubts on this claim.

Three general areas came under attack. First, the assumption of a steady-state biofilm was questioned as to its applicability to practical situations such as RBC reactors and fixed film processes such as biological filters and fixed bed reactors where sloughing off biofilm occurred.

Second, the claim of the authors that their model was verified by independent application to practical examples without parameter adjustment or selection was criticized. It was pointed out that the parameters and coefficients selected from a literature review in fact constituted a parameter selection process. Some of the values of these parameters were questioned - for example the use of a yield of 0.2 g VSS/g BOD and a decay value, of 0.2 day^{-1} would mean that in a biological system a BOD loading of $1.0 \text{ lb BOD/lb VSS/day}$ would produce a steady-state (no net growth situation). This clearly is not the observed situation in biological waste treatment and illustrates the selection of questionable coefficient values by the authors to fit their model to the observed data.

Questions were raised as to whether all of the coefficients selected from the literature were independent of mass transfer limitations. Some discussers suspected that they

were not and therefore when used in the model computations would subject the results to "double jeopardy" since mass transfer effects would be considered twice.

Some discussers were concerned about the general sensitivity of the model to selected parameter values especially since an error in Fig. 2 corrected the best fit line of the model from 40 mg VSS/cm³ to 7 mg VSS/cm³.

The use of the same biological parameter values and coefficients for systems as widely different as RBC's and groundwaters was questioned.

Third, the claim of model verification by the presented data was challenged. It was pointed out that in the anaerobic digestion example the model in one case predicted an effluent with a COD of 100 mg/L while the actual result obtained was an effluent with a COD of approximately 2000 mg/L. The discussor stated that such a prediction would have resulted in an economic disaster. The groundwater model verification was questioned since model predictions addressed changes in COD within 1m of the injection well while the first sampling point was at 11m from the injection well.

IV. CRITIQUE OF SESSION

The three papers formed an excellent theme - that of the kinetics and performance prediction of biofilm reactors. The session brought out the need for further research in the area of biofilm processes. One gets the feeling that the environmental engineering field has just about obtained enough expertise and cross-fertilization from the chemical engineering disciplines that it is ready to launch a full scale attack on processes involving biofilms (and the associated processes involving flocs). Research on these processes may be at the threshold of major advances in understanding. The fact that we are at such a threshold was reflected by the liveliness of the discussion and the excellent attendance at this session. It is also reflected by the great deal of critical missing information in the field. Many contributors decried the lack of availability of good relevant values of coefficients, for example, for: diffusion coefficients for important substrates in biofilms, biofilm densities and reaction rates for various species per unit area of biofilm. Indeed Harremoës stated that there will be no serious biofilm model verification until such coefficients are known with the same order of certainty as the acceleration due to gravity!!

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION
RESEARCH ACTIVITIES

There exists a fruitful field of research in the modelling and performance prediction of biofilm processes especially since such processes are involved in trickling filters, RBC's, land application of wastes, growth of attached aquatic growths, biofouling of structures, biologically assisted activated carbon, activated sludge flocs etc. Considerable potential for the application of modelling techniques, the understanding of process functioning and the improvement of process efficiency exist. Models considering substrate(s) utilization, transport and biological growth will also be important in determining species competition in processes such as RBC, trickling filters and activated sludge.

I. SESSION

- A. Day: Thursday, June 26, 1980
Hall: A
Time: 9:00 am to 12:30 pm
- B. Theme of Session: Physical-Chemical Means of
Treatment of Wastewaters

II. REVIEWER

- A. Name: Donald B. Aulenbach
- B. Position and Affiliation: Professor of
Environmental Engineering
Department of Chemical
Engineering and
Environmental Engineering
Rensselaer Polytechnic
Institute
Troy, NY

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 18: "A General Equilibrium Model for the
Precipitation of Phosphate with
Aluminium," by E. Arvin and
G. Petersen (Denmark)

This study deals with phosphate removal using iron or aluminium salts in both simultaneous-precipitation and post-precipitation plants. The experimental data are closely simulated by a general equilibrium model. The solubility behavior of phosphate in relation to the pH, the dosage of chemicals, the activities of calcium and bicarbonate and the precipitation time are illustrated. Apart from being a pH determining component, the importance of bicarbonate has apparently not been observed before in relation to the precipitation of phosphate with iron or aluminium.

In the paper as presented by Arvin the solubility behavior of iron and aluminium phosphates was described using mathematical models based on either equilibrium or adsorption and included the effects of calcium and bicarbonate on the precipitation of phosphorus. Most previous studies were based on the use of pure substances and did not consider the effects of Ca^{++} and HCO_3^- . One of the common substances in wastewaters is the carbonate or bicarbonate ion. The authors showed that carbonate does play a significant role in the precipitation process and therefore must be considered as part of the model.

The authors indicated that there should be another generalized equation at the top of page 285 relating to the aluminium precipitation. This is the formation of an $Al_x(OH)_y(CO_3)_z$. This was omitted from the original publication.

A mathematical model was developed for the solubility of the phosphorus as a function of a combination of the solubility products of the various forms of phosphate precipitates. From the various combinations of precipitates, values were obtained for constants depending on the composition of the complex solid phosphate, β and ϵ .

The model was confirmed using three types of experimental systems: (1) a simultaneous precipitation pilot plant with the addition of technical grade $FeSO_4$, (2) a full scale post-precipitation plant using $Al_2(SO_4)_3$ with sludge recirculation to the activated sludge plant, and (3) laboratory batch systems of 1 L capacity operated with sludge from the pilot plant for the full scale biological-chemical treatment plant.

The authors showed that the traditional optimum pH for removal of phosphorus is usually in the range of 4.5 to 5.5 for ferric iron and in a range of 5.5 to 6.5 for aluminum. However, in the presence of bicarbonates the optimum was shifted to the pH range of 6.6 to 8.8. The main reason given for this shift was the presence of the bicarbonate ion in the test studies. No other studies using pure solutions included the presence of the bicarbonate. Since the bicarbonate is present in natural systems, the optimum pH would normally be in this higher range.

At low metal to phosphate ratios the bicarbonate activity considerably increases the solubility of phosphate precipitate. Thus, it is desirable to maintain low bicarbonate alkalinity in order to improve the efficiency of phosphorus removal. The influence of the bicarbonate, however, is lessened at molar ratios of metal to phosphorus in the range of two. The increase of metal ratio significantly reduces the phosphorus solubility and may eliminate entirely the influence of the bicarbonate. Also the increase of the dosage tends to shift the optimum pH downward.

In conclusion, the author showed that the phosphate solubility can be reduced by increasing the calcium activity and decreasing the bicarbonate activity. The effect of increasing the bicarbonate activity in increasing the phosphate solubility is more significant at a metal:phosphate

molar ratio of one than at a ratio of two. These results can be shown using the mathematical model and were confirmed in the research studies.

In prepared discussion Wiechers (South Africa) raised eight specific questions based on the studies: (1) The equilibrium based approach is satisfactory, however, the composition of the precipitate varies. On what experimental basis is the model applied?; (2) The model cannot predict the residual phosphorus concentrations by the wastewater characteristics. Experimental procedures must be used in order to calibrate the model; (3) The model does not seem to link the chemical dose to the minimum phosphorus concentration in solution; (4) How can one interpret the possible deviation from linearity in Fig. 1?; (5) The phosphorus precipitates are complex ions; is there any analytical data on the composition of the precipitates?; (6) There appears to be the formation of combinations including dihydrogen phosphate and bicarbonate; how are these accounted for?; (7) It is realized that the presence of calcium and alkalinity are very important in the final solubility of the phosphorus. Was there any consideration of the effect of magnesium upon the precipitate?; and (8) Are there data on the quality of the wastewater or the ranges of hardness and alkalinity since the pilot plant studies were made using actual sewage effluents?

The author provided the corresponding answers: (1) This is a very crucial point. The precipitate is meta-stable and a large surface area is provided in the precipitate. Other than this he could not further quantify the actual results; (2) The paper presents the means of determining constants for the model for each wastewater. There is a great variation in these numbers and therefore experimental studies must be conducted; (3) This is a correct statement. One must find the constants for each dosage. This is one potential weakness of the use of this model; (4) The pP vs. pC relationship varies. Alkalinity plays an important part. Also there is no equilibrium state. Thus, the curve of Fig. 1 could deviate from linearity; (5) They were not able to measure the composition of these precipitates at the present time, but they hope to in the future. This is definitely needed and the use of more sophisticated equipment, such as X-ray diffraction, etc. will be employed; (6) The model is empirical. The presence of dihydrogen phosphates and carbonate do not effect the final result; (7) No studies were made with the use of magnesium; it is known that the presence of magnesium interferes with the crystal structure and therefore would be expected to inhibit the precipitation of the phosphorus; (8) In the wastewaters used, the concentration of alkalinity varied between 0.5 to 6 meq/L. The calcium activity ranged from 20-30 to 60-70 mg/L.

The floor discussion was initiated by Stumm (Switzerland) who stated that the results of this paper agree with the results of others. Phosphorus removal is a complex factor including precipitation, adsorption and coagulation. However, there also are possibly some processes such as occlusion and solid solution. Why is the model called an equilibrium model? Is the model in accordance with the phase rule? Is the substance called a complex solid compound a phase or a diversity of phases? Why did the presence of bicarbonate increase the optimum pH to eight? Why is bicarbonate more effective than sulfate? Again it is suggested that magnesium and other ions be added to the model. If all factors are considered in the equilibrium model, where does colloid chemistry come into the picture? Finally, equilibrium models obstruct the complexities of nature. This model tries to consider all complexities. One must analyze the entire body.

Marais (South Africa) concluded that the paper was amazing and this is the first time he had seen the incorporation of dimensionless numbers into chemistry. The paper initiated new development and has little practical application. There is really nothing in the paper on aluminum and iron precipitation. He concluded by congratulating the author on a job well done.

Lijklema (Netherlands) continued with the comment that no single substance had been defined. Solubility seemed to be related to dosage. The concept was forced on experimental data. Obviously there could be competition between the iron, the phosphate and the other ions in the solution.

Popel (Netherlands) questioned the practical applicability of the model. The constants are specific to each specific situation and, in the case of this paper, specific to the dosage. Is there any chance of any inter-linkage in the precipitate? If there is no inter-linkage, what is the practical application of this model?

In response, Arvin stated that there was an analogy of calcium phosphate precipitation to precipitation using iron, and aluminum. Many studies have been done using fewer chemicals with no interferences. These studies usually include a list of fewer precipitates. In actual cases, results occur more nearly as presented in the paper. This is shown in the human body. Bones and teeth are not pure apatite but frequently form a carbonate apatite, or more specifically calcium sodium phosphate forms in calcified tissue. There was carbonate in the precipitate and sodium calcium carbonate phosphate has been observed in experiments by others. As for the increase in the solubility at $\text{pH} > 8$,

this increase is due to the complex of calcium phosphate which has a greater solubility at pH greater than 8 to 8.5. Also there are more carbonate forms present. This extracts aluminum ion and the aluminum is solubilized. As for the constants being related to dosage, actually the constants are related to the molar ratio of the metal ion to the phosphorus. This is similar to results found by others. The author finally disagreed with Marais' comment in that the paper does have a practical application: it shows which is the more important ion, calcium or bicarbonate, and it can also be used for system control.

- B. Paper No. 19: "Non-biological Elimination Mechanisms in a Biological Sewage Treatment Plant," by C. Matter-Muller, W. Gujer, W. Giger, and W. Stumm (Switzerland)

Non-biodegradable volatile organic pollutants may be effectively eliminated from wastewater in an activated sludge process either by absorption into the biomass of the sludge or by volatilization concomitant with the oxygen transfer to the mixed liquor. The extent of absorption into the sludge solids is determined by a distribution equilibrium between the solids and the liquid and can be predicted from the lipophilicity of the substances as measured by their n-octanol/water distribution coefficient. The volatilization of less lipophilic substances can be related to the mass transfer coefficient of oxygen and can be predicted from the critical volume of these substances. The validity of these non-biological elimination mechanisms was checked in two semi-technical activated sludge processes operated in parallel by establishing a mass balance for four selected indicator compounds indigenous present in municipal sewage. Volatilization and absorption into biomass are of importance in predicting the fate of refractory organic substances in natural waters.

The basic concept of this paper is that not all substances which enter a biological waste treatment plant are broken down and eliminated by biological mechanisms. Some so-called refractory organics are merely absorbed into the sludge while other volatile organic material may be carried away into the atmosphere. Thus, without evaluating the mechanisms of removal one would merely conclude that these substances were eliminated by the activated sludge process. In reality they are merely moved from the liquid phase to either the sludge or the atmospheric phase.

The studies were made with naturally occurring organic material in the Zurich wastewaters. Sufficiently low

detection limits were available so that there was no need to add these compounds in order to study their mass balance in the treatment system. Two lipophilic compounds, n-heptadecane and Pristane, and two relatively volatile organic compounds, 1,2,3-trimethylbenzene and p-dichlorobenzene, were studied in two model treatment plants. It was shown that the lipophilic compounds were transferred to the sludge, whereas the volatile organics were transferred to the atmosphere. Equations were presented for both transport methods. Mass transfer studies showed that with the lipophilic compounds approximately 66% was transferred to the sludge whereas with the aromatic hydrocarbons the transfer to the atmosphere was approximately 72%. It was shown that since the mass transfer efficiencies of these compounds are of the same magnitude, the difference in the mode of elimination is caused by the differences in the extent of sorption into the sludge. That which is absorbed is not available for mass transfer to the atmosphere.

Further, the absorption into the sludge of the lipophilic compound was shown to be directly related to the n-octanol/water partition coefficient. Thus, the degree of absorption into the sludge can be determined by measuring the n-octanol/water partition coefficient; that which is not absorbed into the sludge potentially becomes available for transfer to the atmosphere. Obviously, there can also be some biological degradation of the organic matter.

The prepared discussion was by Balmer (Sweden). He noted that non-biological mechanisms have been observed in petroleum waste treatment where there is very likely removal or elimination of the volatiles to the atmosphere. It was noted that absorption is also important for the transfer of organic material for biodegradation within activated sludge. He noted particularly that data in the paper showed that the lipophilic material was incorporated into the internal lipids of the activated sludge. In other studies starch has been shown to be absorbed into activated sludge in a period of 15 to 20 minutes. Several questions were presented relating specifically to the paper: (1) Is it possible to eliminate absorption outside of the cells?; (2) K_s values noted in Fig. 2 appears to be very high. The equation should be used with caution especially for industrial waste; (3) In the determination of $K_L a$ it is suggested that this be called $\alpha K_L a$ in which α is the ratio of the actual measurements to the standard using pure water; (4) It is shown that the ratio of the mass transfer is independent of turbulence, temperature and similar factors. Is this also true of the α values?; (5) The determination of m^* in equation 8 is not easy for activated sludge. In order to determine the $K_L a$ one needs to determine the oxygen concentration over a time period.

How is the problem of m^* to DO handled? Do you believe the mass balance gives a better estimate of $K_L a$ than simultaneous DO measurements?; and (6) Have experiments been made with other compounds having intermediate n-octanol/water partition coefficients? Also more information would be desired on the recovery of marker compounds in freeze-dried activated sludge.

The co-authors responded that the K_s values were dependent upon the system, the amount of soil material, the activated sludge and other factors which render the K_s values imprecise. In terms of the α factor, they measured the overall coefficient in the experimental work and calculated a value for β ; then it does not matter what the value is for β . It is then also the same for all wastewaters. Other studies have shown that β is dependent on turbulence, but independent of the aeration system. In terms of analytical results, the COD balance was within 10% of the determined value and was used to determine the $\alpha K_L a$ values.

This first floor discussor was Grady (USA) who basically agreed with the conclusions in the paper, but had some concern for certain unwarranted generalizations which were used in that the amount of organic material removed was based on the effluent concentration. If the influent concentration is greater, then there will be a greater percent removal. Conversely, if there is a low concentration of the organic material in the effluent, this does not necessarily mean that the non-biological mechanisms were significant. He is working with influent concentrations of dichlorobenzene ten times those measured here, and getting the same concentration in the effluent due to biological degradation. In the insert of Fig. 2, for what range is the curve linear? As for the main part of Fig. 2, for how many compounds can this line be extrapolated?

Imhoff (Federal Republic of Germany) observed that surface aeration was used in the experimental procedure. There could be as much as 20 times more loss through volatilization than had bubble aeration been used. Were any studies made using fine bubble aeration?

Jenkins (USA) commended the title of the paper, citing the consideration of the non-biological removal mechanisms. Table 1 lists the concentration of marker compounds in the raw sewage. However, studies were made using primary treatment effluent in the activated sludge system. There is no information available as to how much of these organics was removed in the primary portion of the treatment system. It is very possible that the lipophilic material might have been absorbed in the primary sludge. It

was also pointed out that all sludges go to some form of sludge treatment; what is the fate of these absorbed materials in the final sludge treatment? Finally, it was noted that the studies were conducted under equilibrium conditions. Is there any information on the kinetics on the reaction, specifically any response to slugs in a normally operating sewage treatment system?

The co-authors responded that there is definitely a different loss by volatility in different forms of aeration including the use of purge oxygen. This has been studied and is intended to be the subject of a future paper. As to the degree of removal of the organics in primary treatment and pre-precipitation, this information was published at the Stockholm Conference in 1978. Pre-precipitation appears to provide very efficient removal and greasy material aided their removal.

It was pointed out that the objective of the study was not to promote transfer of volatile organics to the atmosphere, but merely to evaluate the degree of transfer. They merely wanted to cancel the common assumption that elimination of organic material is equivalent to removal by biological systems. As to the linear range of the isotherms, it is impossible to distinguish between absorption in the linear range, but they may eventually become asymptotic. Large molecules such as starch may become absorbed. In response to the question on equilibrium or steady state conditions, a steady state model is present in the appendix. There is a distribution between the water and the lipid phase for volatile substances. So far the absorption isotherms have been observed to be linear.

C. Paper No. 20: "Optimal Advanced Treatment and Phosphorus Removal by Deep Bed Filtration," by H. Gros and B. Morgeli (Switzerland)

Flocculation-filtration applied for advanced wastewater treatment and phosphorus elimination is discussed on the basis of practical experience in a medium-sized pilot plant. Filtration allows very low residual phosphorus concentrations to be attained and as the second stage of phosphorus elimination, results in substantial coagulant savings. Data from four computer-controlled parallel filters and long-term filtration tests (including backwashing) show the influence of the main parameters, e.g. addition of coagulant and flocculant aids, height and granulometry of filter layers, filtration, etc. It is thus possible to determine the filter characteristics and its operating conditions for optimal operation in a given case.

Gros indicated in the presentation that there is a stringent restriction on the discharge of phosphorus to Swiss lakes. In order to reduce the phosphorus concentration below 0.2 mg P/L, flocculation-filtration was studied.

Two processes were studied, one was the single addition of iron for the removal of phosphorus; the other was a two-stage process in which the iron was first added followed by precipitation and then the addition of another 2 mg Fe/L and coagulation and precipitation. This two-step process resulted in lower residual phosphorus concentrations using about half as much iron. This two-step process with filtration resulted in residual P concentration in a range of <0.2 mg/L.

Combinations of filter material and filtration rate were studied and the pressure drop, the time of filter run and the backwashing characteristics were evaluated. Other important parameters were bed depth and the type and size of filter material. Studies were also made with the addition of a polymer in addition to the iron. Two types of filtration considered were surface filtration and deep-bed filtration. Surface filtration involved smaller sand grains and a shallower bed height, lower velocities and lower pressure drop. However, larger filtration areas are required than with deep bed filtration. The deep-bed filtration relates to coarser material with higher filtration velocities, a greater bed depth and pressure drop. Coagulants can be used in higher concentration. Because the amount of backwash water needed depends on the wash quality to be obtained and not on the bed height, longer filtration periods reached using the deep bed filtration decreased the amount of backwash water needed. Since greater amounts of coagulant aid may be used with deep bed filtration the amount of iron used may be reduced. Backwashing was improved by the use of air during the backwash.

Basically, the results of the studies showed the optimum location of the filter system and its optimum design with regard to a specific treatment plant. The overall conclusion is that filters will aid in lowering the phosphorus concentration in the effluent to an acceptable level.

The prepared discussion by Kavanaugh (USA) confirmed that filtration is better than plain sedimentation, particularly when it is required that the effluent contain less than 1 mg P/L. He did bring up some questions as follows: (1) In Fig. 1, showing the two-stage process using less chemicals, it is difficult to compare the two methods. There are no data points on the curve and no information on

pH. The difference in chemical requirements could possibly be due to the competition with ions in the single stage addition and to the fact that the filter removes particles down to approximately ten microns. At a constant Fe:P ratio, and more stringent requirements for phosphorus removal in the effluent, there is a saving in coagulant and the filter is essential to the system. However, the comparison should be based on the total phosphorus in the effluent; (2) Is it possible to use granular filters efficiently and economically at higher concentrations of P, for example, in the range of 4 mg P/L?; (3) Pilot plant studies are needed for specific systems: would it be possible to elaborate on the computer control, the sampling, the measurements and the variability of the influent? The filterability number is based on declining rate tests, but the studies were at constant rate; (4) It was indicated that the addition of the flocculant aid increased the filtration rate. At a rate of 5 m/hr, the surface alone seems to work without the polymer. There should be some information indicating the optimum polymer, media, and filtration velocity using the pilot plant; (5) Are the data for Figs. 5 and 6 for surface or depth filtration? and; (6) Recommendations for design should include the design of the coagulation prior to filtration. Evaluating backwashing would possibly require studies over a period of months - even years. Continued evaluation of filter performance is suggested. There should also be some details in the comparison of nitrifying versus non-nitrifying filters. In general more details are needed prior to using the information contained in the paper for the design of a filter.

Gros responded that the paper presents the summary of much data from the plants at Zurich. It was difficult to include the total phosphorus data and the paper presents just one example of the many studies that were conducted. Coagulation filtration can be used wherever one needs less than 1 mg P/L in the effluent. If the influent P level is greater than 2 umg/L (?) it can be handled satisfactorily with a reasonably long filter run. As for some of the additional information on sampling, six sampling points were used and samples were collected using open tubes so that there would be no disturbance of the filter beds. The correlation between turbidity and suspended solids in the effluent was determined for the varying conditions. Only a very low concentration of polymer was used in all of these studies. Other data are available. The difference between the nitrifying filters is basically a difference in porosity of filters retaining biomedial on the filter grains.

The floor discussion was opened by Adin (Israel). He congratulated the authors for using the filter for treatment of the waste, not just for final polishing. He

would like to see more interpretation of the data on a theoretical basis for future prediction and design. It was pointed out that flocculation occurs on the surface of the particles and not in the bulk. Further studies should be made in optimization of the system, for example with the use of the coagulant aid, larger sand grains may be used. In response to this the author stated that he is working on the theoretical aspects. The research presented here was to design a filter and to evaluate a pilot study.

Rupke (Canada) stated that some of the conclusions in this paper may have been different under a different economic situation. For example, simultaneous precipitation in aeration tanks without filtration has produced an annual average effluent quality of slightly less than 1 mg P/L. However, if it is mandated that the effluent concentration may never exceed 1 mg/L, then a filter is required. In Canada an effluent of 0.5 mg P/L can be achieved more economically without the use of the filter. What is the technical lower limit with the use of only coagulants and sedimentation? Balmer (Sweden) questioned whether the method described would be consistently effective under the normal variability of input loads.

The author replied that for a P concentration in the effluent of 1 mg/L, filtration is not necessary. However, filtration may have other benefits such as suspended solids, iron and colloid removal and nitrification. For achieving a concentration in the effluent of less than 0.2 mg P/L, filtration will definitely be needed. Both post precipitation and precipitation-filtration are useful processes.

- D. Paper No. 21: "A Comparative Study of Various Coagulants for the Renovation of Secondary Effluent," by L. R. J. van Vuuren, G. G. Cillie, J. van Leeuwen and J. Prinsloo (South Africa)

Lime, ferric chloride and aluminum sulphate were compared as coagulants for the renovation of activated sludge effluent in a 4,500 m³/d water reclamation plant. All three gave satisfactory results in terms of clarification and phosphate removal, although slightly better results were obtained using high lime treatment. After further processing; i.e. breakpoint chlorination, and filtration, ozonation, activated carbon treatment and final chlorination and stabilization, the reclaimed water was, in all cases, of excellent chemical and microbiological quality.

Two advantages of lime treatment were its softening

properties and the convenience of ammonia removal at the high pH attained. The additional microbiological barrier provided by high lime treatment could be replaced by interstage chlorination during ferric chloride or aluminum sulphate clarification. Ferric chloride coagulation resulted in the lowest water reclamation costs, while high lime coagulation was the most expensive, mainly owing to higher chemical, operational (particularly sludge handling), maintenance and capital costs. The choice of coagulant is determined primarily by the reuse application of the reclaimed water. Effluent quality requirements and particularly the need for ammonia removal are important factors influencing the cost of water reclamation.

Cillie' indicated that this paper is one of a series presented at IAWPR Conferences describing the improvement of methods of treatment of wastes for reuse, and may be considered as an amendment to studies of the high lime unit processes.

Studies were made comparing high lime treatment with treatment using ferric chloride with polyelectrolyte, and with aluminum sulfate with polyelectrolyte. The source of the wastewater was an activated sludge effluent from the Stander water reclamation plant in Pretoria. A two-stage clarification process was used with the lime treatment which included FeCl_3 and polyelectrolyte addition. Ammonia stripping was part of the treatment process, with recarbonation using CO_2 , prior to the secondary coagulation step. The secondary coagulation was carried out using FeCl_3 and a polyelectrolyte. In all cases recycling the sludge was found to improve clarification. The FeCl_3 and $\text{Al}_2(\text{SO}_4)_3$ treatments were similar to the lime treatment process except that the ammonia stripping portion of the system was eliminated and intermediate chlorination was added.

Five different processes were compared: (a) single stage $\text{Al}_2(\text{SO}_4)_3$ clarification, (b) two-stage $\text{Al}_2(\text{SO}_4)_3$ clarification, (c) FeCl_3 clarification with interstage chlorination, (d) FeCl_3 clarification without interstage chlorination, and (e) high lime clarification. Samples were taken at each unit process of the tertiary treatment system: therefore, the quality improvement of each unit process can be evaluated. The one misconception is that the influent to the tertiary treatment system was defined as "raw water" when in reality this was the effluent from the previous activated sludge treatment system. The studies basically showed that there was little significant overall difference in all five treatment methods in removal of turbidity, COD, phosphorus and ammonia. High lime clarification significantly reduced the total hardness,

whereas the $\text{Al}_2(\text{SO}_4)_3$ increased the hardness. Somewhat poorer P removal was shown by the single stage $\text{Al}_2(\text{SO}_4)_3$ clarification. The high lime clarification achieved a significantly lower P concentration after the first stage clarification process, but by the time the complete treatment was applied, the other treatments, with the exception of the single stage $\text{Al}_2(\text{SO}_4)_3$ clarification, achieved approximately the same P removal. There was also a significant improvement in the organic carbon removal with the high lime clarification. All of the iron and aluminum additions increased the chloride concentration, whereas the high lime did not. Increases in chloride could be anticipated from the use of the FeCl_3 .

The lime treatment system was the most expensive and the FeCl_3 the least. The major cost of the lime was the handling of the large amounts of sludge produced. The final handling of the sludge could have a significant impact upon the final cost of the process.

In all treatment processes the final effluent was chemically and microbiologically of the highest potable quality. The concentrations of halogenated hydrocarbons were within acceptable levels. One of the significant problems in the use of the high lime process is the excess formation of scale which clogs pipes and weirs and requires a significant maintenance program. The iron and aluminum treatment systems were recommended for secondary effluents which are low in ammonia content.

The prepared discussion was presented by Theis (USA). He pointed out that tertiary treatment in the USA is primarily aimed towards phosphorus removal. One question was the mechanism of chemical reactions. Calcium forms a crystalline precipitate and can be removed much more readily, and enhances organic removal with the use of activated carbon. On the other hand iron and aluminum precipitates are more amorphous. Good design criteria are needed. Another question was raised regarding the final water quality; it seemed to be of satisfactory microbiological and chemical quality, but what about the presence of trace contaminants? Was there any formation of chlorinated hydrocarbons? In view of the fact that significant amounts of chlorine were used, it is possible that the final treatment for recycling as a potable water supply may require the need for ion exchange or membrane treatment. In response the author cited the description of the hydrolysis of organics in the paper. Also, papers 38, 52 and 55 of this conference covered the questions of trace contaminants. As for the formation of the chlorinated hydrocarbons the chlorine is applied after the first stage coagulation-sedimentation, (and also activated sludge treatment) at which time much of the organic matter

has been removed. Also it was recommended that the recycle ratio not exceed 30% in these systems.

In the floor discussion Wachs (Israel) mentioned the possible need for bioassays. The major advantage of the high lime is that it provides an additional barrier for the reduction of the microbial count. The more barriers there are the better the systems may be. Another concern is with the high chlorination and the possible formation of chlorinated hydrocarbons, particularly inasmuch as activated carbon cannot be considered a dependable means for removal of chlorinated hydrocarbons. Removal of organics expressed as TOC may be considered essentially 100% removal. For potable water reuse the best means of treatment is most important. In response the author indicated that there was some concern for the need for chlorination. However, there is a shut-off valve which is activated if the chlorination system fails. He reiterated that chlorination was applied to primary sedimentation and nitrified activated sludge effluent which has been denitrified.

Law (South Africa) suggested the paper was incomplete in that costs for the disposal of the sludge were not included in the paper. In order to make a proper comparison, Tables 5 and 6 should include information on the cost of sludge disposal. Further it was indicated in the presentation that disposal of the sludge with the biological sludges of the preliminary activated sludge treatment plant improved the sludge dewaterability. Law's experience was to the contrary.

Shelef (Israel) indicated that in Israel reclamation is normally for irrigation; however, occasionally there are people who accidentally drink this water, so that it may be necessary for the high degree of treatment described. He questioned the effect of FeCl_3 on the chloride content in the effluent and the effect as compared to lime on the effectiveness of chlorination if post-chlorination is practiced?

Molof (USA) indicated that in USA the limit for chlorinated hydrocarbons is 100 ug/L. How can a primary treatment plant get down to this level? Also looking at the graphs for COD and TOC removal, it appeared that all treatment processes achieved approximately the same COD removal, but the high lime treatment produced a better TOC removal. What are the health effects? Also the author did (not) comment on the effects of hydrolysis.

Balmer (Sweden) questioned whether or not the aluminum and iron treatment systems were operated at the optimum conditions. How did the authors determine the required dose?

Idelovitch (Israel) indicated that considering only phosphorus removal aluminum and iron treatment may be more economical; however, other parameters are also important. If the use of lime increases the cost only ten percent then this added cost may be considered worthwhile for water reuse. Also the cost of treatment of the sludges may offset the cost benefits of the Fe and Al treatments. Even without considering the problem of chlorinated organics, lime sludge is known to be efficient in inactivating both bacteria and viruses.

The author's response to Law was that no cost data were available for evaluating the sludge disposal cost. Very little sludge was produced. It did not interfere with dewatering because this was not primarily organic sludge since it is part of the tertiary treatment system. With respect to Shelef's question of the impact of the chloride in irrigation, it was pointed out that the study was made for the possible potable use of the water. In this case an additional 20 mg Cl/L would not be of concern, however, it may be of concern if the water is used for irrigation. Also irrigation is not the complete answer, because it is only a seasonal process and treatment must provide for year round problems. In response to Molof's question, the author did not offer any reason for the difference in the COD and TOC removal. The risk from chlorinated hydrocarbons was considered insignificant in this system which was low in ammonia. Finally, in response to Idelovitch's question, it was indicated that there was a high capital cost in the use of the lime system due to the NH_3 stripping. It was also quite energy consumptive; and the ammonia removal in particular is poor in cold weather. The author reiterated the fact that the paper did mention both the advantages and disadvantages of the various treatment systems and individuals should consider each method in terms of their own specific needs and situations.

IV. CRITIQUE OF SESSION

Paper Nos. 18, 20 and 21 fit together in a balance of theoretical and applied evaluation of physical-chemical treatment processes, specifically for removal of phosphorus, but generally for advanced treatment of wastewater. Paper No. 19 was not exactly in the same category, but was very useful in that it indicated that in many instances man's efforts are not the only means of purifying wastewaters. Mechanisms such as absorption and volatilization may result in purifying the wastewater but occur without any intended effort by the treatment plant operator. Frequently, they are overlooked in that only removal is measured in a treatment system and not the mechanism of removal or the ultimate

environment to which the pollutants are removed. All of the papers provided adequate studies to confirm the theoretical concepts.

Paper No. 18 presented a mathematical model which could be used to evaluate the precipitation of phosphate with iron and aluminum. However, laboratory treatability studies must be conducted for each specific wastewater in order to determine the parameters for the model. Once these parameters have been established the model becomes useful so long as the quality of the wastewater does not vary significantly. As with most mathematical models, this one has limited usage, but it cannot replace actual studies on the wastewater of concern.

Of significance was the addition of the bicarbonate as a factor in the precipitation of phosphorus. Too many studies have been made using pure substances to evaluate the degree of phosphorus removal while the removal is really required in secondary effluents. There are many more ions present of varied types and compositions in secondary effluents than in the pure waters with pure chemicals as conducted in many laboratory experiments. It is possible that one of the drawbacks of the use of the model is that it does not consider all of the various forms in which phosphorus can be precipitated. Granted each form can be included in the model, but if the model gets so complicated that it cannot be applied, it is useless.

Paper No. 19 indicated means of removal of various organics by adsorption into the sludge or volatilization into the atmosphere. The more lipophilic substances are normally absorbed into the sludge, whereas the more volatile materials are passed into the atmosphere. Substances which are removed to the sludge have less chance of being volatilized because they have been removed from the system. The studies were well carried out, however, only four organic compounds were able to be used. It would be very interesting to follow-up these studies with numerous additional organics with a wider range of n-octanol/water partition coefficients or various lipophilic qualities. Application of the n-octanol/water partition coefficient can potentially save time in evaluating other organic substances. If a sufficient number of organics can be evaluated in this way not every organic compound needs to be subjected to the tests shown in this study.

Paper No. 20 indicated means for the design of a treatment system involving chemical coagulation and filtration for the removal of phosphate in a tertiary treatment system. It is well recognized that one of the difficulties in normal sedimentation for the removal of

phosphate precipitates is the carry-over of fine particles in the effluent. By removing these in a filtration system, a greater degree of phosphorus removal can be achieved with a conservation of coagulants.

Paper No. 21 is an applied study of various coagulants under different conditions. The studies did show that a high degree of treatment can be achieved using chemical coagulants and that different coagulants may have various applicabilities under various conditions of secondary effluent and/or the final use of the final effluent. It appeared that the lime, which achieved somewhat greater phosphorus removal, offered an additional barrier to bacteria and viruses and accomplished some hardness removal, was also the most expensive coagulant system shown in this study. In many practical situations the need for a specific degree of treatment may be greater than the concern for the increased costs of using lime.

Both theoretical concepts and applied concepts are needed in the wastewater treatment field. This session provided a fair balance between the two, indicating that applied methods must be used in order to evaluate the theoretical concepts. The papers presented here have added to the information needed in terms of evaluating physical-chemical treatment processes and in designing systems for such means of treatment.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Phosphorus removal is of great concern in present day water pollution research. The use of models can aid in the evaluation of the mechanism of phosphorus removal as well as the design of treatment systems for its removal. The realization that bicarbonate interferes with phosphorus removal at low metal to phosphorus doses is very useful; however, other ions in wastewater may also interfere with or improve phosphorus removal and these should be studied in further research.

The practical application of the studies in this session show the benefits of filtration and its limitations. Also, the comparison of the high lime, ferric chloride and aluminum sulfate for phosphorus removal is very useful. Knowing the various means of phosphorus removal which are available one can apply the appropriate method to the degree of treatment needed for any particular aquatic ecosystem. There still seems to be a significant need for further information on the cost of the system studied: even within the one paper there was disagreement in terms of the cost of

the system. Further, it is difficult to compare the cost in that the high lime treatment system includes ammonia removal whereas the other methods do not. In addition to comparing costs among methods cited in these studies, there must be a comparison of costs with other alternative means of tertiary treatment such as various forms of land application.

Each method studied may have a practical application to a specific system for phosphorus removal. However, when considering treatment of water for reuse, other parameters may be more important than just cost, or even efficiency. Reliability may be the most important factor. There should be some form of evaluation of the reliability of each of the system discussed in this session.

In terms of the transfer of organic matter to either the sludge or the atmosphere, there remains considerable work to be done in the field. The ultimate fate of the removed organics must be determined. Two specific directions are required: one is the impact upon the sludge and the transformation of the organics within the sludge, the other is the potential impact on the air and the breakdown of the organic materials when they reach the atmosphere. Only four organic compounds were studied; many more need to be evaluated in order to determine the impact of the physical removal of these organics from the aqueous phase in a wastewater treatment plant.

The design of a treatment system is based upon both the quality of the wastewater being applied to that specific system and to the desired degree of purity in the final effluent. Thus, preliminary treatment processes must also be considered in the physical-chemical treatment methods studied in these papers. An important factor is that laboratory and pilot plant studies are still needed in order to design the most efficient means of wastewater treatment.

I. SESSION

A. Day: Thursday, June 26, 1980
Hall: A
Time: 2:00 am to 4:15 pm

B. Theme of Session: Chemical Treatment

II. REVIEWER

A. Name: Alan H. Molof

B. Position and Affiliation: Department of Civil and
Environmental Engineering
Polytechnic Institute of
New York
Brooklyn, NY

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 22: "Lime Treatment of Wastewater:
Development and Application of a
Simple Graphical Technique for
Predicting the Chemical Composition
of Lime Treated Secondary Effluent,"
H. N. S. Wiechers, R. E. Lowenthal,
and G. V. R. Marais (South Africa).

Wiechers stated that the questions involved in preliminary process selection of chemical systems include chemical requirements, hardness, calcium, alkalinity and sludge produced. For rapid and easy use, a graphical method was developed for lime treated secondary effluents. This would also be useful to plant operations.

The simplified method is based on consideration of the calcium-carbonate system as the only system controlling the chemical response to lime addition. In addition calcium carbonate and magnesium hydroxide activity product constants are used instead of thermodynamic solubility product constants. The difference can be up to two orders of magnitude. The graphical means is described as the modified Caldwell-Lawrence Diagram. Two of the authors previously developed the computer generated modified Caldwell-Lawrence Diagram limited to systems for which thermodynamic solubility constants are used.

Based on batch laboratory tests the activity product constant best characterizing the residual calcium-pH system was $pK_{CaCO_3} = 6.70$. Similarly, the best value for residual magnesium-pH was $pK_{Mg(OH)_2} = 10.5$ for pH values

greater than 10.5. The agreement of the diagram with the experimental values was on the average within ten percent.

The lime dosage-pH diagram shows a difference between predicted and experimental becoming greater as the pH got higher. This was attributed to a non-reactive portion of the lime. The magnesium hydroxide results indicated that the precipitation is not governing below pH 10.5. Rather other effects such as magnesium absorbed on calcium carbonate and magnesium-calcite precipitates govern.

Plant scale data from the Stander Water Reclamation plant in Pretoria, South Africa, and the Lebanon, Ohio pilot plant in USA were used for evaluating the method. The correlation between the predicted and plant values for residual calcium were excellent and for residual magnesium were equally well predicted.

In formal discussion, Minear (USA) questioned the preference of a graphical diagram over a computer model by process design engineers and plant operators. He referred to the Trade-Off Diagram which matches the risk of not representing the system and the difficulty in obtaining a solution. He then raised the question of whether or not the model presented is adequate for general application. The possible use of programmable calculators or minicomputers was suggested. He asked if the authors had compared their results directly with the Merrill and Jorden method. He agreed with the authors' contention that thermodynamic equilibrium constants are not appropriate for real systems.

He asked if the data were only applicable to a seeded system since the batch lab data used a concentration of 10,000 mg/L. The Stander plant comparison was much better than that of the Lebanon, Ohio plant. He questioned the use of $pH = 6.7$ for all pH values. He felt the Stander plant data better fit the use of $pK = 6.7$ than the Lebanon plant and stated that perhaps another value would be better for the Lebanon plant. He felt that the use of a computer approach would better handle variations.

He suggested that the value may be site specific and related to the composition of the secondary effluent such as organic content. In addition this organic could be pH dependent. He suggested a family of modified Caldwell-Lawrence diagrams be constructed for different K values to be used in conjunction with experimentally determined K values.

He did not agree that the magnesium $pK = 10.5$ was a good fit. He suggested a pH dependent K value be incorporated

into the nomographic construction. The use of a system with 10,000 mg/L solids yielding changes of 0.1 to 0.5% with little data scattering (Fig. 2e) was surprising to the discussor.

The author stated that it was a case of computer versus graphical use. He had a definite preference for the graphical method in South Africa. The purpose of the graph was to provide a simple calculation for preliminary process estimates. Then for further depth engineers would go to the lab or pilot plant rather than the computer method. He suggested that computer use by consulting engineers in the USA is more sophisticated and that the facilities and personnel are such that the computer method is preferable. In such instances the author would rather go to the Merrill-Jorden model which would give better results than the graphical method described.

A comparison was made with the Merrill-Jorden method in his thesis. Their data did not yield a $pK = 6.7$. However, their system was flotation with no seed recycle and therefore does not provide a valid comparison. One must provide sufficient time and seed for stable conditions. Therefore, the author preferred Lebanon plant data which had sufficient time and sludge contact to give representative data.

The Stander plant comparison was better than the Lebanon plant. The Lebanon data was year round data points while the graphical method used only an average value. It was difficult to find literature data and the data that were available were too narrow a pH range to make a meaningful comparison possible.

The poorer prediction of data at lower pH values could be due to shorter reaction times. However, the predicted value was greater than the actual value indicating that incomplete calcium dissolution was the reason rather than the shorter retention time. The use of different pH-pK diagrams was not their approach since it is desirable to use only one figure for a beginning effort. For closer results, a computer model would be used.

The magnesium hydroxide fit is not as good as could be. It is probably due to other mechanisms in addition to magnesium precipitation. The comment on analytical accuracy is not needed since the data was derived by calculation from lab data.

Sanks (USA) in floor discussion stated that the South African work on calcium carbonate equilibrium represents a major contribution to engineering in making the

Caldwell-Lawrence diagram workable. He commented that the diagram for 20°C is probably at the best average temperature but noted the need for diagrams at different temperatures. He inquired if the authors would make available the computer program used for the modified Caldwell-Lawrence diagram. Sanks cautioned about results from pilot plants involving CaCO_3 equilibrium if the work is not done carefully. He suggested the authors add a section with pilot plant operation and precautions. He added that modeling the physical characteristics of the clarifier is a big problem. This differs from the ability to model chemical reactions.

The authors stated that the lab experiments were run at 20°C and the Stander plant is at 18-22°C. He was not sure of the Lebanon plant temperature and expected larger variation. It would be useful if one could get different diagrams for different temperatures. He could certainly do it if requested. Also they would make the computer program used to generate diagrams available. This program contains the facility for generating diagrams at different temperatures. He cautioned that the temperature dependence of the carbonic system is not well known and investigation might have to be made on items such as the temperature dependence of calcium carbonate solubility.

The pilot plant operation can be tricky and great care must be taken in precipitation calculations. The biggest problem is scaling. A chapter on running lab and pilot plant lime experiments is contained in his thesis.

Jenkins (USA) supported the $\text{pK} = 6.7$ in a secondary effluent. He said that in the City of Los Angeles plant, calcium carbonate scaling from centrifugation of digested sludge yielded a $\text{pK} = 6.8$. He questioned if raw sewage pK would also be of the same magnitude.

The author replied that he did get a $\text{pK} = 6.7$ for settled raw sewage but he expressed caution since there were large variations in the Merrill and Jorden paper with different types of wastewater and natural waters. He did feel starting with a $\text{pK} = 6.7$ as a first approximation was satisfactory.

J. Bernard (France) asked if the author got data on residual calcium at lower pH 's.

The author stated that his data were only down to $\text{pH} = 10.5$ since the design was based on high lime.

Marais (South Africa) stated that they originally worked out a difficult and complex model incorporating all the factors they could foresee such as salinity effect, ion activity effect and calcium and magnesium ion pairing factors. However, they found that as soon as the solution has phosphate in it, the reduction in solubility products so outshadows the secondary effects that they do not see how improvement could come from a complex formulation since one still has to choose an equilibrium value different from the thermodynamic value. For pure systems, the complex model gives good agreement but the computer is massive and the time is long.

- B. Paper No. 23: "Physico-Chemical Treatment of Wastewater-Control of Reagent Additions by Pollutational Load to be Treated," by P. Marchandise and J. P. Legendre (France).

Marchandise stated that physico-chemical treatment is applicable in towns where the population varies such as winter and summer resorts in France. When reagent is added as a function of flow, as is the usual case, too much reagent will be added when there is a high dilution since the pollution load is independent of flow. To make an efficient use of reagent with no excess, the reagent addition should be a function of the pollution load. The pollution load is measured by a commercial turbidity meter. The turbidity measurement is by a photometer placed in a four L flow chamber. The primary treatment flow is out at the top and bottom to avoid air at the top of the chamber.

The results from two coastal plants, St. Jean de Monts and Nice, show a correlation between COD and suspended solids as a function of turbidity. The linear regression coefficient ranged between 0.9 and 0.95.

In order to determine the chemical dose, a series of jar tests were done on the basis of COD. The chemicals used were chlorinated ferrous sulfate (FeClSO_4) and an anionic polymer. The dose of FeClSO_4 varied from 25 to 150 mg/L for a COD of 64 to 490 mg/L for Nice. The data indicate that jar tests tend to overestimate the reagent dose to be added by about 10-15%. Correlation of COD reduction as a function of raw COD for different dosing levels had coefficients ranging from 0.85 to 0.98. From this, curves were prepared showing percent efficiency as a function of chemical dose and raw COD. With COD greater than 500 mg/L, the maximum dose was recommended at 140 mg/L. Below a COD of 50 mg/L, no chemical should be added.

Pilot plant tests at Nice lasted for six months. Three types of flocculant (FeClSO_4 , $\text{FeSO}_4 + \text{Ca(OH)}_2$, FeCl_3) were tested on two crosscurrent physical chemical plants using lamellar setting tanks at flows of 25 and 30 m^3/h . Influent and effluent samples were taken continuously and composited on a two-hour basis. Chemicals were added both on a basis of flow and loading.

For pilot plant A, the mean efficiency level was 73% with consumption of 88 mg/L of reagent. For pilot plant B, where there were large flow variations and more variable efficiency, the COD efficiency averaged 64% for both reagent control by flow and by loading. However, the reagent dose was at 105 mg/L for the flow control and 81 mg/L for the load control, a 24% savings in reagent.

In conclusion the author stated that two tests conducted at two sites indicate that continuous measurement and regulation are adaptable principles. Advantages are effluent stability independent of load and savings in reagent. More work is needed at more plants.

Chalmers (UK), the appointed discussor, asked three basic questions: Why did they do it, why did they do it this way, and what is the best way to apply their findings? He commented that on a recent world survey he found discontinued physical-chemical treatment (PCT) plants. The application of PCT to domestic sewage is restricted to: pretreatment as an adjunct to optimize biological processes, treatment for seasonal overloads and pretreatment of very strong wastes. He asked if the strong sewage prompted the authors work.

He commented that the data showing that the strength of the sewage is relatively constant at all flow rates was not a normal pattern in his experience. He asked if the flow was a sidestream from a main sewer or is it simply, as we have sometimes suspected, that life is better regulated in France than elsewhere?

He agreed that turbidity is an excellent monitor and asked details of the system, i.e., how it is kept clean. He further commented that the TOC monitor for load leveling in England experienced fairly frequent failures in the analyzer.

The almost direct relationship between COD and SS of strong sewage was "pretty optimistic, if not misleading." He felt that one cannot expect COD removals to be directly proportional to turbidity at all sewage strengths and that this was partly shown by the COD efficiency curves. He added that this is supported by the different efficiencies at low reagent doses where there was 69% removal with 23 mg/L

reagent at A and 38% removal with 17 mg/L reagent at B. He asked the author to comment on the difference.

The real gain of the load-based system is elimination of overdoses for low strength sewage. He suggested peak dosage elimination to increase cost effectiveness and stated that the maximum removal would be restricted between 65-75% COD removal.

Further questions were asked on operating cost, total cost, and optimum removal efficiencies for cost-effectiveness. Other questions were the nature of the primary treatment, location of flow control, strength and frequency distribution of the sewage before flocculation, removal difference between plain settling and flocculated colloidal solids, relative effectiveness of the three different flocculants and sludge produced. He asked if simple flow balancing would justify a constant reagent dosage based on his experience with constant flow being the greatest simple improvement in treatment efficiency.

The author replied that there could have been a higher than 50% variation in load. The data in Fig. 1 do not represent all the variability at a given sampling station. The data used was selected as an illustration. There is no better regulation in France than anywhere else.

Pilot tests to a certain extent were programmed by the sponsors of the project. The rifle diameter in the measurement chamber is two cm. At a flow of 3 m³/h there were no problems in the chamber. However, the feed pump did get clogged. Daily maintenance was necessary to keep things running well. There were no clogging problems in the measuring cell. Therefore, there was no variation of results with time. It was sufficient to wash out on a daily basis. The authors chose the turbidity meter after testing others for other purposes. Of course, it would be preferable to have the element submersed in the flow to be treated. The pretreatment program at Nice includes a degreasing process.

As to efficiency levels, i.e., 69% at 25 mg/L only mean results are used in this table, with the extremes being removed. There are two separate minima and maxima and they do not correspond. The purpose of this table is to show the efficiency range and the range of reagent use. They did not look at the breakdown of the COD. The system could have been tested on more variable pollution loads. The pollution loads at Nice are relatively steady and low.

There were no settling tests done on the sewage before reagent addition and flocculation. Therefore, the

results represent those which would have settled alone and those settled by flocculation. The data are shown for the FeClSO_4 reagent. However, tests with FeCl_3 yielded comparable results. The quantity of sludge produced could not be given. The system based on daily adaptation to the influent load and no other parameter is preferable to a system adding a constant dosage. But this is obviously a question of choice.

• Leentvarr (Netherlands) concluded from the literature that specific conductivity of sewage is a better parameter than turbidity. A multiple linear regression model including selection of sewage parameters, total phosphate, orthophosphate, alkalinity and sometimes a combination of sewage characteristics were a better parameter on which to calculate a coagulant dose.

The question is why did you use turbidity without checking other sewage characteristics? Also, you made a correlation between COD and coagulant dose; this doesn't prove that there is a good correlation between turbidity and coagulant dose. A mathematical analysis may have been possible; also, a statistical approach appears to be missing.

The authors reply that we did not take into account all the parameters that can be used to determine the reagent dose. We used turbidity since we had the opportunity of testing a number of turbidity meters for other studies pertaining to the degree and nature of suspended matter with excellent results. Therefore, we decided to use this equipment for the study. The reagent dose was based on turbidity. A number of jar tests were done based on a priori efficiency level. These tests used turbidity as a measurement of raw water and to determine efficiencies. The results indicate that the use of COD to move from turbidity to a given yield is not out of the question. The authors did not look into math models. The study was part of a broader program and they were unable to get further information and had to process the data available.

Chalmers (UK) asked what exactly the authors were trying to achieve. Is it a complete treatment or is it a pretreatment that goes into further treatment?

The authors replied that biological treatment is normally used in most coastal towns. During peak periods, the PCT process is additional treatment used primarily to remove suspended matter.

Basalo (France) stated that in France when discharging sewage to the sea, two main points are

considered. One is to eliminate suspended matter and the other is to guarantee protection for swimmers and shellfish. The interest in France for PCT relates to suspended matter removal. Possible other uses might include PCT as a pretreatment in small towns for variable and momentary overloads from industries such as slaughter houses.

C. Paper No. 24: "Flocculation of Waste Emulsions Using Polyelectrolytes," C. Axberg, A. M. Wennerburg, and P. Stenius (Sweden).

The paper is concerned with water emulsions containing surfactants which are difficult to treat. A promising approach is flocculation with a cationic polyelectrolyte. The study object was to determine the mechanism of the flocculation. Soy bean oil was the oil part of the emulsion and sodium alkyl sulfates with 10, 12 and 14 carbon atoms was the emulsifier part of the emulsion. There were three cationic polyelectrolytes or polymers used. After the floc was formed, air flotation was used for separation of the floc.

A comparison of the different cationic polyelectrolytes showed good turbidity removal depending on the electrophoretic mobility. The zero point of charge of the emulsion droplets closely matched the optimum polymer dosage. Chitosan, a polyglucoseamine and linear high density polymer, showed the best performance as a polymer due to its high charge density.

Increasing the emulsifier concentration had a larger effect than an emulsified oil increase. When the emulsifier concentration increased, a larger amount of emulsifier is removed. The results indicated that only a minor part of the emulsifier added is associated with the emulsion globules and that the reaction between emulsifier dissolved in the aqueous phase and the polyelectrolyte added is the major factor that controls the polymer flocculation requirement.

The C₁₄ emulsifier with Chitosan polymer gave zero mobility at the smallest emulsifier/polymer ratio. The C₁₀ emulsifier did not reach zero mobility at the highest emulsifier/polymer ratio used. This indicates that the higher molecular weight emulsifiers have a stronger tendency to associate with the polyelectrolyte. In addition to ionic reactions, the hydrophobic interaction is important in the reaction between emulsifier and polymer.

The largest floc size was formed when the electrophoretic mobility was zero. The polymer requirement increased with an increase in the emulsifier chain length.

For the shortest emulsifier the floc size was quite small and due to a low polymer requirement, a low amount of polymer/surfactant precipitate was formed. This indicates that a precipitate is essential for getting high floc strength.

The results indicate that the polymer that is not neutralized by dissolved surfactant is active in destabilization of the emulsifier and the main flocculating mechanism is charge neutralization.

The conclusions included the observations that cationic polymers can be used to flocculate emulsified oil, the basic requirement for flocculation is charge neutrality, the polymer requirement is determined by the concentration of surfactant and the ease of a polymer/surfactant precipitate, the polymer requirement for a given emulsion is dependent on the polymer charge density, a polymer linear structure is preferable to allow bridging to occur and the strength of the floc formed is dependent on the formation of a surface active polymer/surfactant precipitation.

The discussor, Yoshino (Japan), indicated that it was unfortunate that the mixing and flocculation times were not presented. These factors were considered very important to operation, i.e., overdosing flocculant and design of mixing flocculation and settling tanks.

In research conducted by Yoshino, indices to evaluate the effects of flocculation on the separation characteristics included: incremental effects on the settling velocity, incremental effects on the solid removal percentage in the sedimentation process, effects on the thickening velocity and/or dewatering velocity in the packed layer of solid particles, and effects on the porosity in the thickening zone.

Yoshino's flocculation compartment was set up with glass tubes of 150 cm length, connecting to a total length of 80m. A suspension of flocculant, kaolin and water, flows through the glass tubes, upward and downward, alternately until the readings of an electrophotometer were constant, respectively. The flow was shut down and the particles settled. From these results the distribution of settling velocity of suspended particles in each part were determined.

The differences in settling behavior were minor after a certain flocculation time elapsed (4.7 min for inorganic, 1.7 min for organic). It was found for another test that the distribution curve of settling velocity moves toward where the sizes of particles become larger with the

lapse of flocculation time, but become almost the same after a certain flocculation time (4.8 min for inorganic flocculant and 1.7 min for organic flocculant). The discussor stated that it is important to declare the characteristics of suspended solids in the flocculation process.

The author replied that the results showed many interesting points on flocculation of suspension with organic and inorganic flocculants. The results show the importance of flash mixing and flocculation conditions.

Pal (Kuwait), in floor discussion, noted that the commercial polyelectrolyte, Zetag 92, has 2.5 times the charge density of Chitosan. However, under identical conditions, 12 times more Zetag 92 were required to achieve the same flocculation results. What is the cause of this difference? Chitosan flocs were less fragile than the commercial flocs. The Chitosan had a wider concentration range to achieve good flocculation while the commercial flocs have a narrower range. In the literature it is recommended that whenever a linear polymer with high or low charge density is used for flocculation purposes, it is not the flocculation period that is important but the high velocity gradient and longer time period of treatment that is important. The authors used only one min treatment. Could this partly explain some of these problems?

Gehr (Canada) suggested that the previous discussor misunderstood Table 1. Zetag 92 has the lowest charge density since the molecular weight per charge group is inversely proportional to charge density. He congratulated the authors on obtaining molecular weight charge density information from manufacturers. This is a problem in Canada. He asked if they confirmed in any way the manufacturer's data since different manufacturers can measure things differently, especially molecular weight. The authors did not mention the number of replicates per test and therefore there is no indication of the error. Why did they use pH = 6? Different polymers work best at different pH's. Therefore, the pH = 6 may not have been optimum for all three polymers. There is a lot of controversy in the literature on whether zero electrophoretic mobility is required for optimum flocculation. The authors have taken it as true that zero mobility is best. However, for Chitosan the optimum dose in Figs. 2 and 3, depending on the error, could be taken at about 10 mg/L whereas at zero mobility, the dose would be 40 mg/L. This could have a bearing on the results. The discussor agreed with the authors statement that charge neutralization is the most important factor. He had also found with dissolved air flotation that molecular weight is not as important as the charge density of the polymer.

However, the term "charge neutralization" should be used only in specific cases. These are when the Stern-Guoy layer around a molecule has been neutralized. However, in the author's case, it appears that the attachment is electrostatic and flocculation is by the bridging mechanism. Therefore, "charge neutralization" is not the correct term to use for the flocculation mechanism used here.

Balmer (Sweden), in reference to the first discussor, indicated that he doesn't believe the author's objective was to optimize the process, but rather to get technical insights into the flocculation mechanism.

IV. CRITIQUE OF SESSION

Paper No. 22 was part of the ongoing program of South Africa in wastewater treatment with lime. Views on simple graphical techniques versus "computer model" appeared to be based on one's geographical area of work. Since verification of the graphical technique was limited to only two plants, the general applicability was questioned. However, the authors' calcium carbonate pK value was supported in the discussion. The general reaction to the paper was to expand the authors graphical technique such as to temperatures other than 20°C.

In paper No. 23 the use of load controlled chemical reagent additions was a worthwhile goal. But the restricted condition under which the experiments were done including a site with relatively low and steady loads raised many questions. The use of turbidity as the reagent control indicator was especially questioned. The importance of PCT as a remover of suspended matter was stressed.

Paper No. 24 was a narrow coverage on emulsion flocculation. The question of the correctness of the authors data as to the molecular weight-charge density was raised. The use of only pH = 6 was questioned as well as the lack of the number of replicates per test. The technical insights gained in the paper appear valuable.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The subject of lime-treated wastewater is of direct concern due to the use of lime in USA in both water and wastewater treatment. The introduction of a simple graphical technique will better enable researchers, design engineers and operation personnel to better utilize lime treatment and better understand its characteristics. Adaptability of the technique to more examples is needed.

The use of chemicals for flocculation is of great interest to both the water and wastewater fields. The concept of load control over flow control to minimize reagent use is a valuable goal. Whether or not the turbidity technique used in the paper is directly applicable to USA wastewater needs to be investigated.

The pressing problem in USA is emulsions especially industrial wastewaters. The paper describing the flocculation of emulsions with a cationic polymer is of great interest due to its possible applicability in meeting effluent requirements. Since the technique was only tried on a soy bean oil-surfactant emulsion, further work will have to be done to investigate its applicability to different types of emulsions.

I. SESSION

A. Day: Monday, June 23, 1980
Hall: B
Time: 2:00 am to 4:15 pm

B. Theme of Session: Solids Separation and Aeration

II. REVIEWER

A. Name: James H. Reynolds

B. Position and Affiliation: Environmental Engineer;
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III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 25: "The Use of Flow Contractions to
Improve Clarifier Performance,"
P. L. Silveston, J. F. Cordoba-Molina
and R. R. Hudgins (Canada).

The hydraulics of clarifier operation have been concerned until recently with the flow of a homogeneous fluid through a vessel. An operating clarifier, however, must exhibit density stratification if solids are to be separated from the fluid. According to theory, the presence of stratified flow in clarifiers should permit the existence of internal waves in clarifiers. Internal waves should give rise to fluctuations in overflow suspended solids. Of greater significance is that these fluctuations should cause back-mixing which should reduce the separation performance below that predicted by ideal flow models.

Experiments reported in this paper pursue the hypothesis of mixing induced by internal waves and examine the effect of flow contractions on solids removal in a clarifier. Improvements of from five to about 15% in the fractional removal of solids have been found at a high degree of solids removal. These results translate into large decreases in suspended solids discharged over clarifier weirs or large increases in the capacity of the clarifier for the same degree of solids removal. The experiments open up a new approach to clarifier design and offer a class of techniques to produce better performance in both new and existing units.

A slide showing the variation in suspended solids concentration at a fixed depth was presented as evidence that internal waves in a clarifier can significantly affect solids removal. The author indicated that the amplitude of these waves was somewhat a function of the liquid velocity in the clarifier. Data for increasing flow rates were presented indicating that the higher flow rate created the lowest wave amplitude. This information was not presented in the formal printed paper.

Additional data presented, but not included in the formal printed paper, indicated that wave amplitude was greater at the liquid surface than at deeper liquid depths. Measurements were taken at approximately 1, 2, and 3.5 cm which supported this conclusion.

The authors reported that their work had included investigation of several types of flow contractors, including: vertical and horizontal flat baffles, corrugated baffles, wire mesh, and conical configurations. However, this paper only presented the results of the flat baffles and the conical configuration.

- B. Paper No. 26: "Pilot Performance of Deep U-Tubes,"
R. E. Speece, Daniel Gallagher,
Charles Krick, and Robert Thomson
(USA).

U-Tube aeration has received considerable attention recently as part of a modification of the activated sludge process called "Deep Shaft" treatment. Presently there is only limited data on aeration characteristics of deep U-Tubes showing the effect of velocity, depth and gas/water injection ratios. This study determined the increase in dissolved oxygen, the oxygen absorption efficiency and the head loss across a 0.1 m diameter U-Tube for the following parameters:

Velocity	0.9, 1.4, 1.8 m/s
Depth	12, 30, 61, 103 m
Oxygen	4, 7, 1/2, 25% O ₂ /water injection ratio
Air	5, 15, 25% air/water injection ratio

Tap water was passed through the system for all of the above parametric conditions. In addition, 5 mg/L of an anionic detergent was injected into the tap water to simulate domestic wastewater as recommended by the British. Also, in other tests, 100 mg/L of Bentonite clay was injected into the tap water to simulate the colloids in domestic wastewater which provide nuclei for effervescence of supersaturated dissolved gases.

Air injection at 25% air/water injection ratio indicated considerable improvement in $\Delta D.O.$ Using tap water a change from 30 to 61 m depth caused the $\Delta D.O.$ to increase from 11 mg/L to 17 mg/L. When pure oxygen was injected, however, at 25% oxygen/water injection ratio and at 30-m depth, the $\Delta D.O.$ was 68 mg/L and increased to 95 mg/L at 61 m. Negligible increases were noted in $\Delta D.O.$ at 103 m depth.

Over the velocity range investigated (0.9 to 1.8 m/s) there was no significant effect on $\Delta D.O.$ The maximum absorption efficiency for pure oxygen at 7.5% O₂/water was observed to be 52% in the 103 meter deep U-Tube, demonstrating that the U-Tube requires capture and recycle of the off-gases if it is to be used in an efficient manner as the absorption system for an oxygen activated sludge system. The maximum oxygen transfer economy with air injection was 4 kg O₂/kw-hr with 15% air/water injection ratio at 61 m depth producing an effluent containing 21 mg/L D.O. ($\Delta D.O.$ = 15 mg/L 220% saturation). The estimated total cost, amortization and operation, per ton of oxygen absorbed from air would be \$23/ton of oxygen compared with \$42/ton of oxygen using surface aerators which can produce only 2 to 4 mg/L of D.O. in the discharge. The estimated total cost to absorb commercial oxygen at 90% absorption efficiency was \$6.50/ton.

Deep U-Tubes offer excellent potential as energy and cost efficient oxygen transfer systems. However, the optimal

depth appears to be approximately 40 to 60 m for air injection and 25 to 60 m for oxygen.

The formal presentation paralleled the formal printed paper. However, the author emphasized two points not emphasized in the text. First, effervescence of supersaturated oxygen is not a problem as long as the dissolved oxygen concentration does not exceed approximately 60 mg/L. Second, the costs calculated for the pure oxygen system do not include the cost of oxygen production.

- C. Paper No. 27: "Performance of Finned Channel Separator", N. Tambo, K. Hashimoto, M. Sugahara, T. Hasegawa, and T. Onitsuka (Japan).

Conventional sedimentation basins are designed to utilize only gravity acting on flocs as the driving force of separation, and to separate flocs in static flow conditions. The extreme designs of conventional settling basins are slant-pipes (USA practice) and multi-stage slant-boards (Japanese practice) tanks which have the lowest overflow rate with laminar flow regime. The authors succeeded in overcoming the limit of the overflow rate improvement and attaining a much higher efficiency of floc separation by placing fins on the slant-boards in the upright position normal to the direction of flow and admitting flocs into numerous wake vortex streams behind the fins for dynamic separation.

In the study, high efficiency of the new dynamic separation method was proved by experimental and practical

plant studies. Flow pattern of the finned channel was identified by using a flow visualization technic of hydrogen bubbles (electrolysis of water). After the flow pattern and model experiments of floc removal, a mathematical model was proposed to explain the high performance and its numerical constants were evaluated. Through the study it became possible to calculate the performance of the finned channel separator for theoretical design.

The presentation of the author paralleled the formal printed paper. However, the author did add one important piece of information not contained in the paper. The hydraulic residence time of the finned channel is less than ten minutes.

IV. CRITIQUE OF SESSION

The paper by Silveston, et al., was based on a series of previous papers published by the authors. The information presented was supported by a sound theoretical base. This research approaches clarifier performance from a hydraulic viewpoint and neglects the effects of solids characteristics. Further research will indicate the validity of this approach.

More researchers or practicing engineers need to become aware of internal waves in clarifiers. The data contained in the formal printed paper and more certainly the figures contained in the oral presentation, clearly indicate their existence and importance in clarifier performance.

Speece, et al., presented an excellent body of information describing the operation, performance and design of U-Tube aerators. The paper contains the type of practical design information required by the design engineer.

The design information developed is compatible with that provided by the manufacturers of the system. The real importance of the paper lies in the range of operating conditions studied. Generally, the manufacturer's data is limited to a narrow range. The paper by Speece, et al., provides data over a fairly broad range. Additional data, at intermediate points in the range would be useful and would substantiate the conclusions of this paper. Also, the

effects of oxygen uptake by biological organisms on the system would be very useful to the design engineer.

The paper by Tambo, et al., was well documented. It provided an illustration of process development in the United States compared to that in Japan. The finned channel described by Tambo, et al., is similar to the tube settler presently being used in the United States. Each process has attempted to enhance gravity settling of particulate matter.

The hydrogen bubble diagrams shown in Figs. 10, 11, and 12, in Tambo, et al., clearly illustrate the flow pattern of the finned channel. Similar studies of tube settlers should be performed for comparison.

The paper contains data which describe the finned channel performance in treating potable water. A similar study using secondary treated wastewater would be useful to the consulting engineering profession.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The results of Silveston, et al., cannot be applied directly to solve practical engineering problems at this point in time. The data were collected from pilot scale units which processed a synthetic wastewater. However, the concept of internal wave formation in clarifiers should be investigated further. This concept could be especially useful in areas with stringent effluent suspended solids discharge requirements. Proper clarifier design and performance could eliminate wastewater effluent filtration.

The research reported by Speece, et al., clearly indicates the value of the U-Tube aeration system. These results were obtained from pilot plant studies using a synthetic waste. Direct application of these results to practical engineering problems is possible, but somewhat limited due to the nature of the study. This study should be repeated using a prototype system and real wastewater. The low cost and apparent ease of operation of this system suggests that it has real advantages in the wastewater treatment field.

The results of Tambo, et al., should be compared with the performance of tube settlers. These studies should

include comparisons using both potable water processes and secondary treated wastewater. It is possible that the finned channel separator could be used to upgrade existing secondary clarifiers. Research in this area is urgently needed.

I. SESSION

A. Day: Tuesday, June 24, 1980
Hall: B
Time: 9:00 am to 12:30 pm

B. Theme of Session: Environmental Impacts in Marine Waters

II. REVIEWER

A. Name: Clifford W. Randall

B. Position and Affiliation: Virginia Polytechnic
Institute and State
University
Blacksburg, VA

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 28: "Some Factors Involved in the Occurrence and Limitation of Algal Blooms in an Australian Estuary," by C. W. Heath, I. C. Smalls and D. Cannon (Australia).

The authors presented data collected over a six-year period from (1) the mid-estuarine section of the Georges River, near Sydney, N.S.W., Australia; (2) upstream stations; and (3) tributary creeks. The purposes of the study were to: (1) attempt to develop a relationship between physico-chemical conditions in the estuary and phytoplankton development; (2) assess the effects of storms and algal seeding as bloom precursors; and (3) use laboratory algal culture work to more precisely delineate the nutrient growth response of the phytoplankton.

The catchment above the study zone in the Georges River has an area of 635 km² and an urban population of 860,000. Most of the area is sewered and four secondary treatment plants with a combined average daily flow of 26.7 megaliters/day discharge to the headwaters. Sewer overflows do occur during the high intensity storms that characterize rainfall events in the area but are not considered to be an important source of pollution because of their relatively infrequent occurrence and the large stream flows that coincide with them. The rainfall is a rather substantial, 1215 mm per year on the average, but is highly variable and storms of large magnitude are the rule. The freshwater flow to the estuary averages only 2.6 m³/sec, but peaks at 350 m³/sec. The principal freshwater input is from high

intensity, low frequency storm events.

The estuarine zone has a depth range of only one to ten m at low tide, and the tidal range is only 1.1 m. According to the authors, no salinity, dissolved oxygen or temperature stratification occurs at any time in the water column. No nutrient observations were made at the bottom of the water column; all samples were from a depth of 0.5 m.

Phaeodactylum tricornutum Bohlin was used for algal growth potential (AGP) studies. Spikes of nitrogen, phosphorus, iron, silica and all four nutrients in combination were used. A control artificial medium that contained silica ($\text{Na}_2\text{SiO}_3 \cdot 5\text{H}_2\text{O}$, 0.10 mMolar), a vitamin mix (B_{12} , 0.25 mg/L; Biotin, 1 mg/L; thiamin, 1 mg/L), and a salinity of 13‰ to approximate that normally observed in the estuary, was used.

Nutrient concentrations in the estuary at the Sandy Point station had mean values of 0.142 mg/L $\text{PO}_4\text{-P}$, and 0.67 mg/L $\text{NO}_3\text{-N}$. The mean chlorophyll-a concentration at the same location was 12.65 $\mu\text{g/L}$, with a maximum value of 65.67 $\mu\text{g/L}$. By contrast, Salt Pan Creek, a tributary, had essentially equal phosphorus and nitrogen concentrations but much greater chlorophyll-a concentrations, a mean of 39.48 $\mu\text{g/L}$ and a maximum of 227.85 $\mu\text{g/L}$. Similar results were observed in the other tributaries. However, AGP studies with the uni-algal culture found little difference in the growth potential of tributary and main estuarine waters. Further, single nutrient spikes produced little change while combined spikes of the four nutrients gave greater yields. The results indicate that the mid-estuary had incomplete phytoplanktonic utilization of the nutrients present. The lone exception was one case of silica depletion. Why the algae growth was inhibited was not determined.

It was concluded that algal blooms in the main estuary are controlled by storm events and that seeding of algae from the tributaries to the main estuary plays an important role. In general, phosphorus concentrations reached peak values during or immediately after storms, when salinity values were minimum, and then declined as salinity and chlorophyll-a (algal growth) increased. The authors presented a graphical relationship between chlorophyll-a and salinity, but the relationship was considerably more complex than the graph indicated. For example, the storms flushed the algal blooms out of the estuary, but replenished the nutrient concentrations in the surface waters, which then promoted new algal blooms and growth of the algae displaced (seeded) from the tributaries. Nitrogen levels did not appear to be flow related but did approach mean values during storms.

The authors concluded that diffuse sources of pollution are the most important factor in stimulating algal growth in the estuary. Furthermore, the average total phosphorus and chlorophyll-a levels have increased at the main estuary stations each year since 1973 because of increasing development in the catchment. Since complete utilization of nutrients by the algae does not occur, because of undefined physical or physico-chemical constraints, they suggest that the Georges River has additional capacity to accomodate, without detriment, an increase in nutrient loading, and it should be further studied and exploited.

In the assigned discussion, P. J. Ashton (South Africa) noted that the catchment area for the main estuary was ten times that of the tributaries and he asked if this was the reason that algal blooms were not flushed out of the tributaries and, therefore, seeded the flushed estuary. The answer was affirmative. He commented that frequently in natural systems nutrients will be in adequate supply but physical factors such as light and flow rates will limit growths. Asked if light was limiting in the estuary after storms and if it was also limited during the AGP studies, the author replied that light limitation was probably a limiting factor in the estuary but they were unable to quantify it using a Secchi disk. He did not think light limitation was a significant factor in the AGP studies. The discussor asked if the results indicated the estuary could assimilate a large nutrient load and the speaker replied that this management alternative was suggested but other factors could affect the condition at any time and extensive surveillance would be needed if such an approach were taken.

In floor discussion, Randall (USA) noted the similarity between the physical response of the Georges River and the Occoquan Reservoir of Northern Virginia. He questioned the statement, "there is a decline (in phosphate) from high to more typical values before algal growth takes place." He commented that it seems likely that growth is the reason for the decline, rather than a subsequent event. Also, he asked whether the increased nutrient concentrations after storms were the result of mixing higher concentrations from the bottom of the water column with the algal growth depleted top concentrations. The speaker stated that a decline in phosphorus to typical levels did usually precede algal growth by several weeks and he also stated that no stratification of any kind had been observed, therefore, mixing was not thought to be a significant factor.

Nyholm (Denmark) noted that in Denmark, rather than

suggesting that more nutrients could be added to a stream because it had some unused assimilative capacity, the question would be, "what benefits can be derived by further reducing the nutrient load?" He also commented that both light and nutrients were generally limiting at the same time in a natural system rather than one or the other. The speaker replied that, while further nutrient removal from the system was being considered, the current situation was very beneficial to the oyster industry and further nutrients might be more beneficial. He also stated that light limitation was likely a primary limitation in the system because nutrients appeared to be abundant, although some unknown nutrient might be limiting.

- B. Paper No. 29: "Application of Ecological Dynamics for Eutrophication Control in Kobe Harbor Area," by T. Morioka (Japan).

The author has proposed the utilization of dynamic modelling as a planning-management tool for eutrophication control in the Kobe Harbor area of Japan. The Kobe Harbor area is unusual in that the thermocline is at half the water column depth, the tidal currents are weak and very little dispersion of pollutants occurs, breakwaters are so situated that mixing or exchange of the water with that outside the Harbor is virtually prevented, and the bottom sediments contain a very large amount of organic detritus which permits recycling of nutrients to the overlying water. Efforts over the past five years have resulted in activated sludge treatment of 90% of the municipal sewage discharged to the Harbor and a large reduction in pollution loads from industries. This has not achieved a significant reduction in red tides or algal blooms, however, and additional eutrophication control measures are needed. The author proposed dynamic modelling as a rational approach for the selection of the most effective control methods.

The ecological dynamic model selected was a slightly simplified version of those developed by DiToro, et al. (Advan. Chem. Ser., No. 106, pp. 131-180) and Jorgensen (Ecological Modelling, 2, 147-165). This model is based on a mass balance of phosphorus and its transfer among five measurable forms, inorganic matter, phytoplankton, zooplankton, detritus, and sediment. Laboratory and field studies were conducted to define urban runoff inputs, sediment release, diffusion and plankton growth interactions. The model was simplified by neglecting decomposition of organic phosphorus to inorganic forms and other interactions of organic phosphorus. The model was first used to estimate the reduction of phosphorus that would have to be accomplished to achieve eutrophic control and was

then used to evaluate the following management alternatives: (1) advanced sewage treatment and source reduction of phosphorus detergents, (2) dredging of bottom sediments (3) urban runoff control and (4) filtration of sea water.

The model predicted that dredging would be the best countermeasure to reduce the growth of phytoplankton, that restriction of phosphorus detergent use by households would be as effective as advanced wastewater treatment, that filtration of sea water would be an ineffective control method, and that AWT with 70% phosphorus removal plus detergent use restrictions and regional road cleaning would be cost effective methods for water quality improvement. The author recommends that each policy be carried out in the appropriate time and space, supported by intensive field surveys. He also notes that the model needs refining in terms of improved modelling of the decomposition of organic phosphorus and the release of nutrient from the bottom sediment.

W. E. Scott (South Africa), the formal discussor, commented that modelling is becoming more important as a tool to provide information for planners and to define research needs. He noted that the model assumed that phytoplankton was light limited but did not account for seasonal changes in species, vertical movement of zooplankton, and organic phosphorus in the sediments. He stated that the real test of any model is "how well it reflects what is actually happening." On that basis, he believed the author's model was successful and he concluded that the paper was very valuable.

The author replied that the model was intended to be general rather than species-specific and agreed that more intensive studies of algal species, sedimentation rates and nutrient release were needed.

Ahmed (USA) commented that the model needs statistical evaluation. He questioned the assumed effectiveness of street cleaning since studies in the USA have indicated it is not very effective. He asked why other methods of controlling stormwater runoff were not evaluated.

The author replied that statistical evaluation was not done because the results are preliminary. He admitted that the street cleaning results were based on assumptions and that no actual data were available. He noted, however, that results in Osaka showed that the suspended solids removed by street sweeping were high in phosphorus content and he commented that, based on two observed storms, ten mm of rainfall was enough to wash off the street surfaces.

C. Paper No. 30: "Long-Term Changes in Benthic Fauna Resulting from Sewage Sludge Dumping into the North Sea," by H. Caspers (Germany).

The author reported on a ten-year study of the effects of sewage sludge dumping on the benthic fauna of the North Sea, beyond the mouth of the Elbe. Sludge has been dumped in the area since 1961, but information about the benthic fauna in the area before dumping began is available for comparison. The area affected by the dumping is about 30 km², and about 22,000 m³ of sludge are disposed of each month.

Since 1970, benthic samples from the dumping area and from areas outside the dumping area have been collected on a regular basis (several times a year) at about 120 stations. The sediment has also been characterized with respect to particle size, water content, pore volume and organic-inorganic carbon content.

The results show that biotic desolation of the benthos has not occurred because of the sludge dumping. In fact, while dumping has resulted in a shift in the dominant specie of bivalves, the successful specie, Abra alba, has reached massive populations in the dumping area. Several polychaetes have also established large populations in and around the sludge disposal region. However, great variations in the populations of individual species do occur from year to year and instability can be viewed as a characteristic of the sludge dumping region. It is clear that sewage sludge deposition is not a lethal factor for all of the benthic species and generally encourages the growth of adaptable species. Whether these changes should be classified as ecologically negative requires further discussion and investigation but the species diversity of the dumping area is not significantly less than the rest of the southern North Sea. The area is simply much more productive.

The deeper layers of sediment were generally anaerobic but the tidal movements ensured that at least a thin oxidized surface was present at all parts of the dumping region, a very important factor for the development of benthos. The heavy metals in the sediment 40 cm beneath the surface had concentrations of the same order of magnitude as those in the surface sediments. Furthermore, there were no significant differences between the samples from the dumping area and the controls taken outside the region as far as heavy metals were concerned. Apparently, any potential increases have been effectively masked by the heavy metals introduced to the entire outer Elbe region by the river

outflow.

The author concluded that the results suggest that the deliberations of the Oslo and London Conventions, wherein international agreements were made that the introduction of non-toxic waste materials into the sea will not be permitted unless their disposal on land is impossible, should be reviewed and possibly overturned.

The formal discussor, Halley (UK), for H. Fish, asked whether the author was for or against sludge dumping at sea. He noted it was clear that the USA was going to completely ban the practice but he felt on the basis of emotion and political expediency rather than reason. He stated that others do not want to be swept along into such a ban unless it is based on sound scientific evidence. He related that the United Kingdom is the world's largest disposer of sewage sludge at sea (11×10^6 wet tons/year) and the practice has been going on for 85 years. He further stated that his organization (Thames Water Authority) disposes of 5×10^6 wet tons/year in this manner and reported that England appointed a committee to study this practice a few years ago and the study was completed in 1978. Copies of that report are now available from the UK National Water Council and Department of the Environment for the sum of \$7.00 Canadian. The report concludes that sea disposal of sewage sludge in the UK coastal waters is an environmentally acceptable practice. Then he noted that what may be true for one area may not be for another, which points out that blanket or uniform regulations are not only illogical but irresponsible considering the costs of alternatives. He stated that each area was important enough to be assessed and regulated on its own.

The discussor asked for further clarification of the heavy metals survey and of long and short-term effects in the dumping area. He asked why a new sludge dumping area had been selected.

The author replied that he believes dumping should continue in the same area. A decision has been made to dump in a different area that is further offshore but the change is for political reasons, not scientific. The premise is that the area is being moved to protect beaches and recreational areas but it is unlikely to make a significant difference. It will make it more difficult to monitor and control the dumping area, however, in addition to increasing the cost of disposal and requiring larger ships.

R. Pomeroy (USA) stated that sea disposal of sewage sludge in Southern California off Los Angeles has been

studied by the Southern California Coastal Research Project and the organization has concluded unequivocally that there are no detrimental effects of such a practice. He commented that he believes the USA would alter its stance on sea dumping of sludge.

W. Stumm (Switzerland) cautioned that the consideration of sludge dumping in any sea area should carefully take into account local conditions. He noted that the North Sea area studied by Caspers was very favorable but other locations might not be. He also noted that while heavy metals are usually considered, chlorinated hydrocarbons have not been and efforts should be made to determine the concentrations present and whether or not they will accumulate in the food chain.

Schellmann (Germany) asked if there was any difference in what other cities on the North Sea coast of Germany were doing with their sludge. The author replied that they have just started secondary treatment and are just beginning to realize they have a sludge problem. Whether they will be permitted to dump into the sea is a political question that hasn't been answered yet.

L. Ellis (UK) stated that studies in Liverpool Bay since 1970 have produced essentially the same results as those reported by Caspers; there are no detrimental effects. He stated that he disagrees with Caspers' interpretation of the Oslo-London accords. He believes the proper interpretation is that sea disposal can be used. The London Convention states that consideration must be given to the practical alternative of land based methods for rendering the sludge less harmful for sea disposal. The Oslo Convention did not ban sea dumping either. He believes that the sea's assimilative capacity should be used but with careful monitoring. He noted that the UK Department of the Environment has several publications on the monitoring of sewage sludge dumping at sea performed over the past ten years. Four very thick volumes for 14 British pounds are available; write to the National Water Council, Queen Anne's Gate, London.

L. Mendia (Italy) summarized by saying that the consensus is that ocean dumping should be used, but only after careful evaluation of total environmental effects.

C. Paper No. 31: "Variability of Bacterial Counts in Coastal Waters," by A. L. H. Gameson (UK).

The establishment of bacterial standards for coastal waters affected by sewage discharges and the monitoring of

the waters is greatly complicated by the wide temporal variability in observed bacterial counts that commonly occurs. The author has attempted to provide insight into this problem by presenting the analyzed results of a large number of coliform observations for several British beaches and by comparing his results to that obtained by other investigations, including two in Southern California. Because counts tend to be log normally distributed, he suggests that the results be expressed in terms of the median and the antilogarithm of the standard deviation of the logarithms of the data. The latter term is given by the square root of the ratio of the 84.134-percentile to the 15.866-percentile, and denoted by ρ .

Altogether, the author has summarized the results of 17,584 samples, collected at 104 stations, located at nine different beach sites, for his analysis. All samples were collected in the sea near the water's edge, and analyzed for total presumptive coliforms. The counts were very variable at most sites but there were large differences between sites which bear no relationship to either the number of samples examined or the geometric mean count obtained. There was a fair degree of consistency between each of the stations at any one site. Ratios of the 95 and 90 percentiles to the medians, when plotted against the corresponding ρ -values, conformed well to the theoretically predicted straight line. The values of P_{99}/P_1 when plotted versus ρ also approximated the theoretical straight line, although there was considerable scatter.

The results show that intensive sampling over a one- or two-day period would provide inadequate information on which to establish a general level of bacterial counts in coastal waters. The author recommends that, if the bathing season is of interest, sampling should be spread throughout the season and that sufficient data should be obtained to determine whether they tend to be log normally distributed so that confidence limits can be assigned to the geometric mean count. The author also discussed the implications of dual standards such as those used in the USA (level should not exceed a log mean of 200 per 100 ml, nor should ten percent exceed 400 per 100 ml) by EPA for bathing waters. In many cases, the 400 per 100 ml for ten percent of the samples would become the more stringent part of the standard.

J. Vial (France), for E. M. Nupen, stated in his formal discussion that he was impressed by the measures and approaches and will attempt to use them himself in future efforts. In reply to a question from the author, he stated that in France small numbers of samples are collected and are being interpreted without respect to variability. The results

are published for the public.

L. Henry (Australia) observed that whether regulatory agencies wanted to or not, in Australia they must select a number as a standard for enforcement purposes and then must publish the sampling results in the newspapers. If the standard is low (1000) and an occasional sample is high (10^6), the public gets very upset. Asked how the author would recommend handling this public relations problem, the author replied that the "magic" numbers should be selected on the 90 to 99 percentile rather than the mean or medium.

J. Gannon (USA) agreed with the author's approach but suggested that he use a graphical plot of his data to overcome (avoid) statistical problems. This has been done for many years in the USA.

Oldam (New Zealand) asked if legislative standards should have different levels for harbor areas as compared to open sea areas. The author replied that he is not in favor of standards at all and believes that each site should be judged on its own merits.

Ross (Canada) asked about the variability of fecal coliforms as compared to total coliforms. The author stated that he wished there was more information on that but he has some information which indicates that fecal coliform variability is a little less than the variability of total coliforms.

Reazuman (USA) noted that storm events will frequently cause samples to exceed 90 to 95% values. He asked how these occurrences should be incorporated into the standards. The author did not provide an answer for the question.

L. Mendia (Italy) summarized by saying that total water quality should be evaluated rather than just coliform counts when making decisions on the safety of bathing water and he agreed that the variability of coliform analysis is a very important topic.

IV. CRITIQUE OF SESSION

The authors presented summaries of long-term data collection efforts and the results, in general, have considerable world-wide implications. All of the papers interfaced with regulatory procedures and the general tone of both the authors and the discussers was against blanket regulations and for the evaluation of each site on its own merits for subsequent regulation.

Paper No. 28 illustrated the difficulty of trying to establish why algal blooms do or do not occur in estuaries and how complicated the formulation of control strategies can be. In general, nutrients were not fully utilized in the main estuary and algal growth was limited by physical conditions rather than scarcity of nutrients. Because storm events trigger the onset of blooms, however, control efforts must center on non-point pollution controls. In subsequent discussions with I. C. Smalls, he commented on the fallacy of attempting to control algal blooms by controlling nitrogen in point source inputs for both estuary and freshwater bodies of water. He noted that considerable money had been wrongly spent on such efforts in Australia.

The concept that because physical factors were limiting algal growth, therefore, the estuary had more assimilative capacity that should be exploited, was applauded by some but strongly criticized by others. Such a policy may be very dangerous and potentially disastrous since the factors controlling such systems are not defined, or controllable, and a critical environmental factor might change.

The importance of Paper No. 29 is that it illustrates a management approach. Efforts should be made to perform "management run" simulation of eutrophic systems before control strategies are formulated. Using this approach, controls that are likely to have an insignificant impact can be discarded and initial efforts can focus on controls with the highest probability of success. Of course, because of fallacies in the initial simulation, extensive monitoring of effects must be performed to correct the course of the management approach.

Paper No. 30 stimulated the liveliest discussion in the session. Many people, particularly the British, are fearful that a worldwide ban on the dumping of sewage sludge at sea will become a reality. Apparently there is a large body of data, including this paper, which argues against such a ban. In fact, it seems likely that, in most instances, dumping of sewage sludge at sea is an environmentally sound practice that should be utilized. Apparently one or two bad examples have wrongfully slanted regulatory and public opinion against the practice. Again, careful monitoring is essential and research on biomagnification of chlorinated hydrocarbons is in order.

Paper No. 31 focused on a vexing problem that regulatory agencies face, the temporal variation of bacterial counts for samples collected at the same site, and attempted to provide an analytical and regulatory solution. Interest

in the proposed approach was very high. The implications of using a "two-tiered" standard and the potential unwitting stringency of it was clearly explained.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The similarity between the Australian estuary and American estuaries, for example, the Chowan River estuary in North Carolina, is striking. The likelihood that physical factors such as flow patterns, light penetration, etc., are limiting algal growth, rather than nutrient concentrations, is probably true for the majority of the North American estuaries. This, however, simply illustrates the excessive enrichment of the estuaries with respect to nutrients. The demonstration that blooms are controlled by storm events and non-point sources of pollution reinforces similar conclusions for both freshwater and marine bodies of water on the East Coast of the United States (e.g., Chowan River, Occoquan Reservoir and Chickahominy River in Virginia) and highlights the importance of research on best management plans for non-point pollution abatement. The fallacy of trying to control eutrophication through nitrogen control alone deserves special emphasis for USA research.

An important observation related to the Kobe Harbor modelling effort is that optimum management dictates that the management model be selected prior to the design of the monitoring effort to insure the collection of all data pertinent to the model. Of course, additional information can also be collected to avoid the oversight of important factors that were originally assumed to be insignificant. A research need is for the development of overall models that interface watershed models with receiving water models. The watershed models should include both point and non-point sources of pollution. Further characterization of non-point sources, particularly wetlands areas and delivery coefficients for upstream areas, is badly needed. Also typical efficiencies of best management practices are unknown and nutrient recycling from sediments needs extensive research.

It seems clear that a great deal of information on the effects of sewage dumping on marine benthic fauna has been collected, both in this country and elsewhere. Research should probably focus on developing approaches for the evaluation and monitoring of specific sites and on the effects of exotic chemicals such as chlorinated hydrocarbons on the food chain.

With respect to bacterial count variability, the

principal effort should apparently be directed towards the education of regulatory personnel with respect to the implications of establishing "two-tiered" standards and those based on median or mean values. Research into the variability of fecal coliform counts and, possibly, the relationship to pathogen variability (viruses, etc.) also appears to be in order.

I. SESSION

- A. Day: Tuesday, June 24, 1980
Hall: B
Time: 2:00 am to 4:15 pm
- B. Theme of Session: The Fate of Wastes Discharged
into Coastal Waters

II. REVIEWER

- A. Name: Mesut Sezgin
- B. Position and Affiliation: Research Associate
School of Civil
Engineering
Georgia Institute of
Technology
Atlanta, GA

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 32: "The Role of Bottom Deposits in the
Oxygen Regime of a Polluted Estuary,"
A. James (UK)

This paper dealt with the effect of bottom muds on the dissolved oxygen (DO) distribution in the River Tyne estuary. In the paper the estuary is imagined to be divided into five reaches of six km each. Within each reach, studies on the benthic deposits and the water mass were conducted. Investigations on the bottom muds included the measurement of the organic content and the oxygen uptake rates of the benthic deposits. Studies on the water body were carried out for determining the vertical distribution of DO and biodegradable organic matter and oxygen consumption rates. The rate of addition of organic matter to the estuary was estimated from the data obtained through surveying. Reaeration rates were calculated from hydraulic and hydrographic data.

The results indicated that the organic content of bottom muds and the oxygen uptake rates varied between 9-19% and 0.5-0.95 g O₂/m²·hr, respectively. Apparently there was no relationship between these two parameters.

Based on calculated DO and organic matter (ultimate oxygen demand, UOD) fluxes in the Tyne estuary, more than 50% of oxygen consumption occurred in the bottom deposits and BOD exerted in the water body was relatively insignificant. Most important organic removal occurred due to dredging.

Reaeration from atmosphere was also reported to be an insignificant source for oxygen compared to the quantities introduced by advection from upstream.

James discussed the effect of wastewater discharges on the DO distribution in the Tyne estuary and the current research on the effect of some environmental conditions on the oxygen uptake rate of the bottom desposits. The Tyne estuary is connected to the North Sea. There are no major wastewater discharges along the river. BOD of the river water entering the estuary is approximately two mg/L. However, the estuary itself receives mostly untreated wastewater discharges from a population equivalent of over two million. These wastewater discharges create anaerobic conditions in the estuary for a period of two to three months each year. The Water Authority responsible for the estuary set standards for migrating fish which stated that the river shall contain a minimum DO concentration equivalent to 50% of saturation at all times. To meet the requirement of the standard, a plan which required collection and subsequent treatment of all wastewater discharges around the estuary was proposed. The approach was to investigate the waste assimilative capacity of the estuary in combination with different degrees of treatment to meet the requirement. The author constructed one and two dimensional dispersion models and observed that organic material was removed at a high rate. In order to fit the model to the required DO distribution curves, high reaeration coefficients had to be used.

Organic matter discharged into the estuary remains in suspension or solution and is oxidized there or transported to the sea. The remainder settles and is oxidized in the benthos or is removed to sea by dredging. Oxygen enters the estuary through the surface and is consumed in solution and by the benthos. The current research was conducted to determine the relative importance of these processes in organic matter removal and DO depletion.

It was found that organic matter removal was mainly due to dredging and more than 50% of oxygen consumption occurred on the bottom deposits. Advection from upstream was the most significant source of DO in the estuary. It is suggested that if the above observations are proven to be correct, the conventional mathematical model which describes the oxygen flux mainly in terms of changes in the water mass should be modified to represent benthic fluxes.

The author discussed the current research being conducted on the oxygen requirements of benthic deposits which included the effect of some of the environmental

factors on the oxygen uptake rate of bottom muds. He found that the oxygen uptake rate of bottom deposits varied linearly with temperature. An exponential increase in the oxygen uptake rate was observed with the increase in the velocity of overlying water. Since the velocity of the overlying water changes throughout the tidal cycle the oxygen uptake rate also varies during the tidal cycle. The author commented that the lack of agreement reported in the paper between the organic content of bottom deposits and the oxygen uptake rate was mainly due to the fact that some of the samples collected throughout the estuary contained toxic chemicals. If these data were ignored, a good correlation would be obtained between the oxygen uptake rate and the organic content of bottom muds.

It was estimated that the depth of benthal deposits was 1.5 m and it would take 70 years to oxidize these with the existing conditions assuming that no dredging took place.

Bischofsberger (FRG), the assigned discussor, commented that the paper contained much interesting information on a polluted estuary. He suggested that there were many basic problems which had to be solved before deriving a relationship between DO and the rate of organic discharge. In estuaries it is relatively difficult to measure DO, flow conditions and the oxygen uptake rate of bottom muds, because every installation of instruments on the bottom to measure the oxygen uptake rate causes disturbances of the hydraulic flow conditions and influences the oxygen supply. Therefore, he felt that the author's field measurements with the mud-chamber respirometry would not give consistent results. He also requested some more details of the mud-core respirometry method.

Bischofsberger stated that the benthal uptake depended upon many factors including temperature, DO and the turbulence conditions in the estuary. He, however, commented that a representative parameter of turbulence in estuaries had not yet been developed. He emphasized the importance of bed load movement and hoped that further studies would be conducted to gather information on material transport and the metabolism which would incorporate original estuary bottom muds and simulated hydraulic conditions when conducted in laboratory.

Bischofsberger questioned the validity of DO budget without having conducted a nitrogen budget in the estuary. He addressed the parameters influencing DO budget and nitrogen budget which included sedimentation, resuspension, resedimentation, incorporation in biological material as well as nitrification and denitrification. He referred to his

research work, in which there were some irregularities in the nitrogen budget, which was presumed to be caused by the above-mentioned parameters.

He also commented that the author had used calculated reaeration rates in the determination of the oxygen budget, whereas referring to his experience, Bischofsberger observed that there were great differences between calculated and measured reaeration rates for which he used a tracer method (Tsivoglou) to measure reaeration rates of several streams. He, therefore, suggested the use of measured reaeration rates instead of calculated ones. In his conclusion, Bischofsberger commented on the predominant influence of benthic deposits on DO conditions in the Tyne estuary and hoped that further research would be conducted both to confirm the up-to-date results and to transform the knowledge to other water bodies.

In floor discussion Lijklema (Netherlands) commented that because of the fresh water flow into the estuary there might have been a stratification in the estuary. In modelling DO in such an estuary a two-dimensional model should have been used. In that case, a vertical dispersion coefficient should have been determined for the use in the model.

He further commented that in Table 3 of the paper, the sediment respiration rate was reported as $0.1 \text{ g O}_2/\text{m}^3\cdot\text{hr}$ or $2.4 \text{ g O}_2/\text{m}^3\cdot\text{day}$ and BOD decay rate was $0.4/\text{day}$. But in Table 5 where DO fluxes in the Tyne estuary were given, there was a difference in the oxygen consumption rates in the water and in the mud by a factor of four. He asked the author to explain how he obtained these values.

He further asked the author whether or not the oxygen uptake rate in the sediments was proportional to the square root of DO concentration of the overlying water. He stated that the author measured the oxygen uptake rate by measuring the decrease in DO concentration in the overlying water in an enclosed system. However, if the author had measured the oxygen uptake rates in a system where water was pumped through the system so that DO concentration in the overlying water would have been constant, the author would have found values different than the ones obtained using previous methods. He further commented that if the oxygen uptake rate of mud varied with the square root of DO concentration, the oxygen uptake rate within the sediments would vary with the variations in the DO concentration of the overlying water. Since the oxygen uptake rate of sediments was a function of porosity (or water content) and depth he asked the author how he sampled and whether or not he would

have the same porosity for sediments before and after sampling.

Azkona (Spain) citing his work on the Bilbao estuary which had the same size and low BOD as the Tyne estuary had, stated that he found that 50% of the total oxygen uptake in the estuary was demanded by the sediments. He observed that spring tides were more important than the neap tides in modelling the estuary and it was impossible to model the estuary for the two tides at the same time.

He also commented that nitrification was not occurring in the estuary and they thought it was because of heavy metals. He found that it was very difficult to grow nitrifiers in the laboratory where there was a considerable change in salinity. He asked the author whether the change in salinity would change the rate of nitrification.

McKeown (USA) requested the author to comment on whether or not he observed a clear solid-liquid interface over the sediments, how well his in situ measurements compared to the laboratory measurements for sediment oxygen demand (SOD) and whether or not he had been successful in incorporating velocity effect into the model for handling SOD. The discussor commented that they had observed a linear velocity effect on SOD within certain ranges that they were using.

Snodgrass (Canada) asked the author to answer the following questions: (1) In case of a significant transfer of organic matter from the sediments to the overlying water during tidal net flow, there would be an increase in UOD of the estuary water. Did he consider the effect of organic matter transfer from the sediments in his model for UOD and DO?; (2) Did he observe significant methane production by the sediments? Methane volatilizes and goes to atmosphere, hence it represents an independent sink or export of organic matter of the estuary. In Hamilton Harbor, Lake Ontario, the discussor found that approximately one g CH₄/m²-day was exported from the sediments at a 10°C increase in water temperature; (3) Did he have significant respiration from algae relative to ammonia and/or carbonaceous BOD kinds of sinks for oxygen?

The discussor stated that some of the tracer techniques for estimating reaeration rate would typically run for a day, two days or three days' spread. Therefore, that would presumably represent what the reaeration rate was during that period of time and might vary with wind conditions.

In reply to Bischofsberger, the author explained that in the mud-core technique, a sample removed from the sediments was covered by river water and was stirred with a magnetic stirrer while DO was measured. The uptake rate was calculated from the decrease in oxygen concentration in the overlying water. The author said that they were experimenting with different rates of stirring and different sizes of stirrers to try to get velocities which were similar to those experienced in the river water.

In the mud-chamber experiment, the water inside the chamber was being circulated by an immersible pump. With this technique, it was possible to adjust velocities to the same range as found in most waters. However, the author agreed with the discussor that the level of turbulence provided with the pump may not be the same as observed under natural conditions.

The author stated that they had constructed a nitrogen budget for the Tyne estuary and found very little evidence of the existence of any nitrification in the estuary water.

The author responded that they had estimated the reaeration rates using various critical equations and curve fitting techniques in a mathematical model but the author agreed that one improvement in their field measurements would be to use a tracer technique in modelling of DO in estuaries.

In reply to Lijklema, the author commented that the degree of stratification within the estuary varied with the fresh water flow. At low fresh water flows the estuary was relatively unstratified. Therefore, they tended to use a one dimensional model for that situation. The author stated that they had a two dimensional model but the difficulty was to relate all the hydraulic transfer coefficients with the vertical stratification. With respect to DO effect on the oxygen uptake rate by the sediments, the author responded that they found no effect of DO at concentrations above 1.5 mg/L. However, once the DO fell below about 1.5 mg/L the rate of uptake decreased linearly with a decrease in DO concentration. By the time the DO concentration was around 0.5 mg/L, the uptake virtually ceased.

In reply to Azkona the author agreed that spring tides were much more difficult to handle in the model than neap tides. He referred to another study in which investigators at Birmingham University had faced a similar problem. In reply to the question on the effects of salinity on nitrification rate, the author cited the work on Thames estuary where nitrification had occurred quite successfully

provided the DO levels were suitable.

In reply to McKeown, the author said that in the majority of the estuary they had experienced liquid-solid interface. However, it was sometimes difficult to distinguish from the overlying water. He also commented that they had related oxygen uptake rate to the surface area of the bed rather than the volume of overlying water in the modelling of DO in the estuary.

Finally, the author commented about various sources and sinks of DO. He said that the algae, at the moment, were relatively insignificant in the Tyne estuary. They had found considerable sulfide production in the estuary. He said that his group just started to look at the proportion of oxygen uptake by the mud which was chemical oxygen demand as opposed to bacterial. He commented that the majority of the oxygen uptake by bottom muds was due to chemical oxygen demand and it was possible to separate these two using phenol as an inhibitor.

- B. Paper No. 33: "Investigations into Sewage Grease Behavior in Coastal Waters"
A. Davidson, J. F. Easey,
J. J. Varjavandi and K. M. Warner
(Australia)

The major objective of this study was to examine the movement, dispersion and deposition of oil and grease discharged into the coastal waters off Sydney, Australia. The effluent from a primary treatment plant contained, on the average, 70 mg/L grease and oil in the three distinct sewage fractions: (1) scum, (2) middle, and (3) sludge. Radioactive ^{198}Au was used to label the grease and oil in the sewage.

The areal and vertical dispersion of the ocean discharged sewage had been measured for two sewage fractions under a variety of weather conditions. Both the radioactively labelled middle and sludge fractions exhibited the same dispersion characteristics in the ocean after release from the outfall. The surface pattern and depth profiles showed similar behavior for both fractions. Both sewage fractions were surface trapped in the upper six m of the ocean. However, vertical mixing of the surface trapped layer took place under the influence of strong wave action.

The paper described the techniques used for generating the radioactive isotope, ^{198}Au , labelling different fractions of sewage grease and oil and developing isoactivity charges which could be used in determining the

areal dispersion pattern of sewage under a variety of weather conditions.

The Malabar outfall which serves one million persons out of three million, with the bulk of Sydney's industry was chosen for the sewage grease dispersion investigation. Wastewater from the Malabar catchment is treated at the Malabar Water Pollution Control Plant which is essentially a primary treatment plant. This plant removes approximately 45% of total grease present in the influent.

The scum fraction is the fraction of grease which floats at the surface. Its quantity approximates about five percent of total grease. Since primary effluent is discharged through submerged effluent collectors, the scum fraction is effectively removed at the treatment plant.

The middle fraction corresponds to the fraction of grease which is in suspension either by itself or entrained on other material. It is not removed at the Malabar Plant and comprises about 40% of total grease.

The sludge fraction is that present in the settleable fraction of influent wastewater. It makes up approximately 55% of total grease; 75% of it is removed in anaerobic digestion. Therefore, in the effluent of the treatment plant, the grease was essentially in the middle and sludge fractions.

The dispersion characteristics of grease were investigated using a radioisotope tracer, ^{198}Au , which has a half-life of 63.8 hr. ^{198}Au emits enough radiation to be detected in water while at the same time emissions are low enough for the material to be handled without excessive shielding. It is also relatively inexpensive. Initial laboratory studies indicated that the middle fraction and the sludge fraction could be labelled with ^{198}Au easily. However, some difficulties were encountered in labelling the scum fraction. Therefore, field studies were concerned with the labelling of middle fraction and sludge fraction. Irradiated gold (^{198}Au) as a solution of aurochloric acid ($^{198}\text{AuCl}_4^-$) was pumped continuously into the end of the settled effluent collection channel when labelling middle fraction grease and into the sludge line when labelling digested sludge. Under the pH and redox conditions of sewage, the gold was reduced to the metallic element which was adsorbed by the grease and solid components of the sewage effluent. After the injection of the tracer, the radioactivity in the sewage field was monitored from a boat off the Malabar outfall using scintillation detectors. Both horizontal and vertical distribution patterns were established.

The findings indicated that both the middle fraction and sludge fraction exhibited the same surface pattern and depth profiles. After release from the outfall, sewage rose to the surface and was trapped in the upper six m of the ocean. In the case of strong wave action, vertical mixing of the surface trapped layer did occur. Once sewage rose to the surface its movement was dictated by the prevailing weather conditions. Westerly winds moved the sewage field away from the shoreline. Under mild on-shore winds, the sewage travelled parallel to the shore. The experiments had shown that a ten-fold dilution of sewage effluent occurs within 100 m of the ocean outfall.

The authors developed isoactivity charts from short pulse injections which defined areas of equal radiation intensity. It was proposed that these charts produced a picture of the steady state form of the expanding pulse from non-equilibrium data. The authors suggested that short pulse injections of radioisotope could be used in place of continuous injections which required long periods of monitoring to obtain a picture of steady state dispersion.

Azkona (Spain) discussed the paper in place of A. E. Thorne (S. Africa); referring to his experience with radioactive tracers, such as ^{82}Br , he commented that injection of radioactive tracers into the seawater could be considered as a pulse labelling. Therefore, radiation counts obtained from such a pulse labelling could not give the image of a steady-state situation. Instead, the radioactive iso-concentration curves were displaced with the water currents.

He suggested that in these cases, a mathematical model such as the one proposed by Okuba was required to evaluate the eddy diffusion coefficients. These coefficients, then, could be used in a mathematical model of dispersion. Azkona stated that it looked like the authors had overcome these difficulties, partly, because they used real sewage in their studies and partly they supposed that grease and oil behaved like a conserved substance. Azkona agreed that if grease and oil behaved like a conserved substance such as sodium chloride the rapid dilution and the steady-state picture given by the isoactivity charts could be considered as a dispersion pattern for sewage.

However, he stated two reasons why grease and oil could not be considered as conserved substances. When sewage injected with radioactive aurochloric acid mixes with sea water, many components of the sewage follow Fick's law for molecular diffusion. But, due to its hydrophobic nature, grease and oil may not follow this law. If the emulsified and

labelled oil is de-emulsified it will tend to concentrate and float and the radiation counts will, then, tend to concentrate in the vicinity of the discharge, giving the impression of a very rapid dilution that, in fact, is not really taking place. The other reason is that the aromatic part of mineral oil is not degraded in the anaerobic digester but it can be subject to microbial attack in the aerobic sea water environment.

Azkona suggested the temperature and salinity profiles should have been determined during the radiation counting so that the behavior of oil and grease could be compared with that of a conserved substance. If this had not been done the investigation would have been restricted to the study of the grease and oil behavior. If the comparison had already been made and no great differences in the behavior of oil and grease and any other conserved substances were observed, the experiments indicated the general dispersion patterns of sewage. If this was the case, it could be concluded that a good method for ocean disposal assessment had been developed.

Azkona further requested the author to comment on two questions: (1) What analytical procedure had been followed to determine the grease and oil content of the different fractions?; (2) Did the authors have an explanation for the dramatic decrease in the grease content of the beach sand (more than 90%) when the overall reduction provided by the treatment plant was not more than 45%?;

In floor discussion, Gameson (UK) asked two questions: (1) Are you satisfied to label the solids by colloidal pure metal?; (2) How are you certain that you labelled grease rather than total solids?

In reply to Azkona, the author stated that they had not developed a mathematical model for the problem. However, for the sake of academic reasons, they intend to develop a mathematical model. The author said that they had not used ^{82}Br because it had a shorter half-life of 35 hr, whereas ^{198}Au had a half life of 63.8 hr. Warner responded that in the vicinity of the Malabar outfall the ocean current and the flow of effluent were more predominant than any diffusion currents; therefore, they did not think that diffusion currents would affect their results in any way. He agreed with the discussor that grease and oil might have been subject to biological reaction. The author said that the dilution ratio quoted in their paper was realistic and had been checked using other techniques. The data from dye tracer technique and E. coli die-off rate technique indicate that a ten-fold dilution in the first 100 m occurred. The

author said that they had not conducted vertical dispersion measurements at places very close to the cliff edge because it was not safe. Therefore, their studies were confined to the area approximately 100 m away from the actual point of discharge.

In response to Azkona's specific questions, the author said that they determined grease and oil by chloroform extraction. The author pointed out that although the treatment plant removed only 45% of grease and oil, because of dilution and the natural process of degradation, the levels of grease and oil were low on the beaches. They observed beach contamination when they only used raw sewage or partly treated sewage.

In reply to Gameson the author said that they were satisfied with the method of labelling the solids. The material which was found to be radioactive was collected and taken to the laboratory for radiological and chemical examination. It was confirmed that it was grease.

- C. Paper No. 34: "Movement of Mercury from Minamata Bay into Yatsushiro Sea," A. Kudo (Canada), S. Miyahara (Japan) and D. R. Miller (Canada).

This paper summarized the results of a four-year study together with the previous studies on the movement of total mercury and methylmercury from Minamata Bay into Yatsushiro Sea. Mercury concentrations in the bed sediments of Yatsushiro Sea were observed at 24 sampling locations during 1975 through 1978. The majority of the bed sediments contain less than one mg/kg of mercury. However, the movement of mercury from Minamata Bay, within which sediments contain up to 300 mg/kg mercury, into the surrounding area of Yatsushiro Sea has accelerated during the recent years. During the period of 1960 through 1975 approximately nine tons of mercury moved out of the Bay while roughly 17 tons moved out from 1975 to 1978. The methylmercury content of the sediments of Yatsushiro Sea also increased from 0.56 tons in 1975 to 0.66 tons in 1978. Future movement of mercury in these sediments appears to be predictable and may serve as a model for the migration of other contaminated bed sediments.

The paper presented by Kudo basically addressed movement of total mercury and methylmercury from the Bay. The author reported that both total and methylmercury content of the bed sediments in Yatsushiro Sea increased between 1975-1978 although they were less than one mg/kg. The authors showed that total mercury concentration of the sediments decreased with distance from the point of mercury discharge. Based on

these observations, they estimated that the total amount of mercury in the sediments of Minamata Bay and Yatsushiro Sea was 107 tons compared to 150 tons found in previous studies and the rate of movement from the Bay into the sea was 0.016 km/yr.

Assuming a background total mercury level of 0.1 mg/kg in the sediments, the authors determined the total quantity of mercury moved during 1960-1975 and 1975-1978 to be 9.32 tons and 16.83 tons, respectively. They estimated that half of mercury (75 tons) would move out of Minamata Bay by 1996 if mercury moved at the same rate as that occurred between 1975-1978.

The methylmercury content of sediments was not determined analytically, but the authors developed a relationship between total mercury and methylmercury using a literature survey of 21 field data and 11 laboratory experiments. Using that relationship and the values of total mercury determined previously, they estimated methylmercury content of sediments. The results indicated that methylmercury content of sediments of Yatsushiro Sea increased from 0.562 tons in 1975 to 0.661 tons in 1978. The increase of methylmercury in the sea was 5.8% per year compared to that of total mercury of 42% per year.

The author commented that since average detention time in the Bay was 2.5 days and the sediment contamination was still high after 20 years, water movement itself without a bed sediment movement had little to do with mercury movement. It was claimed that sediment movement was perhaps due to the artificial force caused by navigation of ships and boats because the velocity of water body created by tidal action was not strong enough (< 5 cm/sec) to carry the sediments out of the Bay.

Kudo suggested that mercury might have a tendency to create extreme "hot spots" of contamination in biomass and bed sediments before its dilution and dispersion at the discharge site and they could become extremely critical when the discharge occurred at a small area such as the Bay.

Desorption of mercury from contaminated bed sediments to the water phase was reported to be slow. It was estimated that removal of half of mercury from the sediments by this mechanism would take about 700 years.

The assigned discussor, Bilstad (Norway), divided his discussion of the paper in two main parts: (1) sampling procedures and analytical techniques, and (2) analysis of data in modelling and prediction of mercury movements.

Bilstad emphasized the importance of this type of research and commented that the sampling procedures and analytical techniques were not described in the paper, but they were reported in the internal university reports in Japan. He questioned whether or not they were internationally accepted procedures and why they were not reported in more available literature. Bilstad stated that analyzing parallel samples in Canada and Japan as the authors did and obtaining approximately the same values for mercury concentration would not make the analytical technique valid because the same persons obviously monitored the analysis in both places.

He also questioned the validity of the values reported in Table 1 in which total mercury concentrations were reported with three digit accuracy after the decimal point at mg/kg level. He asked whether an atomic absorption spectrophotometer was used because methylmercury is quite volatile and easy to lose. He commented that in Table 1 25% of mercury values showed a decrease from 1975 to 1978, whereas the authors reported an increase in mercury content of sediments from 1975 to 1978.

Bilstad asked about sampling procedures and whether or not core sampling was employed. He also asked how mercury content varied with sediment depth.

Commenting on Fig. 3, Bilstad claimed that a straight line would fit the data better than the curve given by the authors. He suggested that more data points were needed within a distance of 200 m from the outfall to plot a curve through the points. He also claimed that the dimension of scaling factor, A, should have been $\text{mg/kg}\cdot\text{km}^2$ instead of mg/kg and suggested that the authors should have used another symbol for the mass of mercury because the symbol, A, as the way the authors used it had two different meanings. He further asked how the authors arrived at the factors, of 80,000 and 1,334 in calculating the total amount of mercury.

Bilstad asked about the correlation coefficient of the straightline relationship and the confidence intervals employed in Fig. 4. The authors' straightline relationship developed in Fig. 6 was rejected by the discussor on the ground that the data points were scattered.

Finally, the discussor stated that this type of research, predicting diffusion rates of mercury and mechanisms causing this diffusion was important. By employing proper analytical techniques and statistical methods, it would provide valuable information.

In floor discussion, Kerim (Egypt) asked the authors

whether or not they had analyzed the form of mercury which had been moved out of the Bay either as mercury nitrile, mercuric chloride or mercuric oxide.

Gameson (UK) commented that the authors found that the rate of mercury movement from the Bay during 1975 to 1978 was nearly ten times as great as the rate for 1960-1975. He asked the authors how they justified making predictions as far as 1996 on how much mercury would have been moved out on the basis of this great acceleration in the rate. He further raised two questions: (1) Why has the acceleration occurred?; and (2) Are you assuming that this acceleration will continue up to 1996?

In reply to Bilstad, Kudo stated that they could not perform extensive research because of the lack of funds and the difficulty associated with the nature of the study. Kudo cited the work carried out by USA National Bureau of Standards in the Ohio River area and said that their findings indicated that the sediments were entirely heterogeneous but not uniform. When one takes a sample from a location and samples again, it is possible to have a 50% difference in the mercury content of the two samples. Kudo emphasized the difficulty of sampling in an open sea and said that in an open area it was not easy to collect even ten samples every year.

In response to Kerim, he said that they had analyzed only total mercury and they were going to analysis methyl mercury as well as dimethylmercury.

In reply to Gameson, Kudo stated that he did not have any clear idea why mercury had moved out from the Bay. However, he assumed that increased activity of navigational ships and boats resulted in mixing up the sediments. This, in turn, accelerated the movement of mercury.

IV. CRITIQUE OF SESSION

The feeling expressed by the authors as well as by the discussers is that modelling of environmental systems is very complex and difficult although some progress has been made to solve some complex problems associated with modelling.

Paper No. 32 was a presentation of the preliminary results for the Tyne estuary. Perhaps this was the primary reason for having a lively discussion for the paper. The paper included only DO and UOD distribution in the water body and oxygen uptake rate of sediments. However, in determining the magnitude of uptake of oxygen by the bottom sediments, it

is necessary to make a complete mass balance for DO as well as for nitrogen. The paper did not include some of the sources and sinks of oxygen and organic matter. However, with an active discussion, it was clear that considerable work had been conducted by the author and more research is in progress.

Some of the studies currently being conducted by the author include the use of different type and size of stirrers for simulating natural conditions of rivers and estuaries in laboratory studies of oxygen uptake rates of bottom deposits, developing a two-dimensional model for the DO, determining the proportions of oxygen uptake by bottom deposits as chemical oxygen demand and bacterial oxygen demand.

As the author stated, Paper No. 33 did not present much in the way of findings. It was also not well organized and it included much repetition. Although use of radioactive tracers in dispersion studies of sewage in coastal waters is not new, use of ^{198}Au is a new application in studies of dispersion of grease and oil. The author indicated that they intend to construct a mathematical model for the dispersion of grease and oil in the future. The cost of a single test was 5,000 Australian dollars (approximately 6,000 U.S. dollars) which included the cost for preparation of radioisotope and handling and transportation to the test site.

Paper No. 34 lacked appropriate data analysis. For example, although only total mercury concentrations were determined, the authors made predictions as to the movement of methylmercury which was not analyzed, but estimated, using the poorly defined relationship based on the data from the literature survey. Besides, the paper included many statements without quantitative support. It was indicated that additional studies on mercury movement will be carried out by Japanese government, which will spend 18 million U.S. dollars in the future.

V. SIGNIFICANCE AND VALUE TO WATER POLLUTION RESEARCH ACTIVITIES

The information given in this section was concerned with the fate of organic and metal discharges into the marine environment. Although the methodology and findings are not new, the papers certainly contributed to the existing knowledge in this area. The author of Paper No. 32 had previously developed a method for in situ measurement of benthic respiration which can be used in current studies in the USA. Also, considerable information with respect to ongoing research was presented by the author in the discussion section. Therefore, anyone interested in working

on DO modelling in estuaries may contact the author to obtain more information not presented in the paper. One interesting aspect of the current study was that over 50% of the oxygen consumption occurred on the bottom deposits. Although this has been observed in freshwaters, that was not the case for Thames estuary.

In Paper No. 33, the authors described a method for determining horizontal and vertical dispersion of two sewage fractions using radioactive isotopes. This approach may be useful in studies that are currently being conducted involving the dispersion of grease and oil in the coastal waters discharged from some coastal cities. Again, the paper does not contain much of the available information as the authors stated. Therefore, additional information on this subject may be requested from the authors.

In Paper No. 34, the authors were concerned with the movement of mercury from the Bay into the open sea. It is a four-year study with 15 years of supportive data. With the recent interest in the fate of toxic materials in the United States, this paper and the other internal reports in Japan may serve as a base to those interested investigators in the USA.

I. SESSION

- A. Day: Wednesday, June 25, 1980
Hall: B
Time: 9:00 am to 12:30 pm
- B. Theme of Session: Measurement and Fate of Organics
During Reclamation

II. REVIEWER

- A. Name: Bruce E. Rittmann
- B. Position and Affiliation: Asst. Professor of
Environmental Engrg.
Dept. of Civil Engineering
University of Illinois
Urbana, IL

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 35: "Development and Application of a
Technique for the Determination of the
Molecular Mass Distribution of Organic
Compounds in Water," O. O. Hart (South
Africa)

The author described a technique for analyzing the organics in wastewater by Sephadex gel chromatography. A 50-fold concentrated sample (10 mL) was placed on a Sephadex 15 column and eluted with 0.05 M NaCl at 30°C. Ten-mL fractions were collected and assayed for Total Organic Carbon (TOC). The relationship between molecular weight and retention time was calibrated with sugars.

This technique was applied to samples taken from the Stander water reclamation plant (South Africa). Two treatment trains, one having chlorination and the other having ozonation prior to carbon adsorption, were sampled. The authors showed how the TOC in each molecular weight fraction changed during treatment. Key results include the following: (1) The four fractions eluted from the column after compounds with an apparent molecular weight of 26 were completely eliminated by ozonation; (2) The most prominent fraction, constituting about 30 percent of the TOC, had an apparent molecular weight of 330 to 780; (3) Through the entire reclamation process, all fractions were removed by about 90 percent, although the larger compounds ($MW \geq 780$) were removed largely by sand filtration and smaller molecules were mostly removed by activated carbon or ozonation.

N. Tambo (Japan), the invited discussor, presented a lengthy set of data on his own Sephadex work. Tambo first questioned the use of 0.05 M NaCl as the eluant. Since his own work showed that NaCl elution gave poor recovery, Tambo used distilled water to elute sugars and 0.1 M NH_4OH to elute phenolics. Second, the discussor suggested that TOC was not a good measure since it is not related to biodegradability. He suggested that the ratio of TOC to light absorbance at 260 nm be used.

Discussion from the floor centered mostly on details of the analysis. In answer to various questions, Hart stressed that the purpose of his fractionation method was to provide a relatively simple technique. For example, Hart felt that ten fractions provided a meaningful separation of the total organics, but were still few enough that further analysis, such as toxicity, could be performed. The claim of simplicity must be viewed in relation to other separation techniques because the method, which gives 70 to 95% recovery, requires six hours for the gel separation and up to one day for concentration.

Paper No. 36: "The Fate of Organic Micropollutants Through an Integrated Wastewater Treatment/Water Reclamation System,"
J. F. J. van Rensburg, A. Hassett,
S. Theron, and S. G. Wiechers (South Africa)

The authors described an integrated wastewater treatment and water reclamation system which involved treatment of raw sewage by denitrification, chemically aided clarification, nitrification, chlorination, sand and dual-media filtration, activated carbon adsorption and final chlorination. The integrated system was presented as an alternative to adding advanced-treatment processes after secondary treatment. They challenged the integrated system with 40 $\mu\text{g/L}$ spike feeds of 19 organic micropollutants of known or suspected health hazards. Samples were taken at various points in the treatment plant, extracted with methylene chloride and ether, and assayed by gas chromatography with flame-ionization and electron-capture detection. Samples from potable water supplies were similarly analyzed.

One objective of the study was to determine if the hazardous compounds would be reduced to concentrations less than published hazard limits. When the spike was added to the raw sewage, the concentrations of the compounds were generally reduced to levels less than the hazard limits after denitrification and clarification. When the spike was applied after the biological treatment, activated carbon

reduced almost all of the concentration to below the detection limit. The authors noted that the potable waters generally had higher concentrations of the hazardous organics than the reclaimed water.

The invited discussor, Barentsen (Netherlands), expressed concern over public health aspects of using reclaimed water and the possibility of terrorist sabotage. The author replied that the reclamation system might provide better public health protection against contamination because of its greater capacity to remove organics, compared to normal water treatment.

Some discussion from the floor was critical of the author's conclusion that the reclaimed water was safe. Criticism included the following points: (1) The health-hazard criteria for individual compounds are not necessarily valid; (2) Ecological systems are often even more sensitive than human systems, and these types of effluents, discharged to waters, may not be safe; (3) The fate of the compounds removed in the biological processes were not reported; (4) The activated carbon has only limited capacity; (5) No reliability data were presented; and (6) Although the reclaimed water apparently had better quality than potable waters, neither the potable waters nor the reclaimed water were necessarily safe.

Paper No. 37: "Reactions of Ozone with Aromatics in Dilute Aqueous Solution: Reactivity and Biodegradability of Oxidation Products,"
B. Légube, B. Langlais, and M. Doré
(France)

Distilled water containing 2×10^{-4} M phenol, hydroquinone, aniline, 2,4-D or MCPA was ozonated with a 50 mg O_3/L gas feed for up to 120 min. Individual compounds, as well as TOC, TOD, chloroform-forming potential, iodoform-forming potential and toxicity, were measured during the reaction.

They found that the original compounds were completely eliminated in 30 to 40 min., but that ozonation products, measured with TOD and TOC, continued to decline for up to 120 min. Chloroform- and iodoform-forming potentials increased as ozonation intermediates were formed, although they declined after about one hr of ozonation of phenol and aniline. Ozonation products of phenol, possibly hydroquinone, paraquinone or pyrocatechol, were inhibitory to bacterial respiration. Thus, some ozonation products may be more hazardous than the original contaminants, and partial

oxidation by ozone may be more harmful than no or complete oxidation.

The formal discussor, L. Lash (USA), desired more information on toxicity, catalysis, cost and ozone residuals. The author replied that, based on other work, the bacterial toxicity measure gave an accurate indication of the relative toxicities to other organisms. No work was performed on catalysis or cost estimates but the author suggested that superoxide radicals may be involved in the reactions. Finally, he replied that ozone residuals were all very low in order that the reaction be limited by ozone transfer.

One discussor from the floor pointed out that Japanese workers have shown that pH and temperature are very important in determining the ozonation kinetics of aromatics. The authors did not study temperature effects or control reaction pH. Another question concerned ozonation of polycyclic aromatics. Although the authors had not studied polycyclic aromatics, Neufeld (USA) replied that he had found that polycyclic aromatics in coal-gasification effluent were converted to phenol during ozonation.

D. Paper No. 38: "Removal of Mutagenic Compounds in Wastewater Reclamation System Evaluated by Means of the Ames Salmonella/Microsome Assay,"
R. Denkhaus, W. O. K. Grabow, and
O. W. Prozesky (South Africa)

Three Ames Salmonella strains were utilized to test the mutagenic activity of reclaimed water samples that were collected from a full-scale reclamation plant after activated-sludge treatment, coagulation/settling, ozonation, activated carbon adsorption and final chlorination. These samples were extracted at acid, neutral and basic pH with methylene chloride and concentrated by drying. Salmonella plates were inoculated with 0.1 mL of the concentrated extracts, incubated with and without addition of liver preparation at 37°C for 48 hr and counted for revertant colonies. The number of revertants per plate were compared to controls of distilled water carried through the same procedures.

The results showed rather low mutagenics activity at 10^4 concentration. Neutral and acid fractions had most of the revertants and most of the mutagens showed frameshift activity. Liver preparation had little effect on numbers of revertants. Ferric chloride clarification removed most of the mutagenicity and this was accomplished because organics were removed from the water and because the specific

mutagenicity of the organics present in the water after clarification was less than in the feed water.

Baines (Scotland), the assigned discussor, raised five points. First, he felt that the long period between samples may make comparison of mutagenic activity at different points in the reclamation plant invalid. Second, he asked if the final chlorination added mutagenicity. Third, he wanted to know the health significance of the levels of mutagenic activity. Fourth, he asked if the absence of stimulation of mutagenicity by liver preparation was a good sign. Finally, he wanted to know if the activated carbon columns could have released mutagenic compounds.

Grabow replied that he felt that the samples were fairly homogeneous over time. To the second and third points, he replied that chlorination had no effects in his study and that he had no idea of the health effects of the observed levels of activity. The lack of response to the liver preparation is a good sign, he said, since it suggests that the mutagenicity would not be enhanced by human ingestion. Finally, the author indicated that the activated carbon columns were nearly exhausted and may have released some mutagenic compounds for that reason.

The discussion from the floor was focused mostly on details of the experimental procedures. For example, could histidine in the samples have caused revertants? How was the amount of organics per plate controlled and could this explain the higher incidence of mutagenicity and toxicity of the feed water? How was toxicity measured and is it related to mutagenicity? Were volatiles lost? How good is reproducibility?

The author replied that negative controls had shown no effects of histidine but the mass of organics per plate was not controlled. He claimed that toxicity, which is measured by death of negative controls, is not related to mutagenicity. Most volatile organics were lost. Although reproducibility for one plate is not known, the tests were run with five-fold replicates.

One potentially important contribution was made by Matsui (Japan) who reported that Japanese workers were using the REC assay, which utilizes special mutants of E. coli that have a deficiency in a DNA-repair enzyme. If the compound causes DNA damage, the mutant bacteria will not survive. Matsui reported that the REC assay seemed to be more sensitive than the Ames assay. However, the two tests do not measure the same effect, and the Ames test has been more widely validated and linked to the survival of mutant cells. Matsui's

comments point out that many alternative microbial assays are present but their significance for health effects are undefined.

IV. CRITIQUE OF SESSION

Paper Nos. 35, 36 and 38 were very similar in concept as they applied an assay procedure to a full-scale reclamation system. Because the results they obtained represent very large efforts and are of good quality, the papers are potentially valuable contributions to understanding the performance of advanced treatment systems. On the other hand, all three suffered from a lack of conceptual generalization because attention to the mechanisms of contaminant removal and the ultimate fate of the contaminants was lacking. Although much good data were obtained, application of the results to other systems is difficult. Paper Nos. 35 and 38 were also hindered because the nature and significance of what was measured by the analytical techniques were largely unknown.

Paper No. 37 provided the most directly applicable information because it was designed to measure the rate of oxidation of aromatic organics and the generation of products. It demonstrated important time-dependent changes of product composition, including oxidation state, toxicity, and haloform potential, and it presented a reasonable chemical reaction scheme to explain the results. The paper could have been more valuable, however, if pH control had been practiced, if the literature had been more thoroughly consulted, and if the laboratory results had been related to ozonation practice.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The major significance of this session is to point toward future research studies which address the mechanisms involved in the various processes and the significance of the measured parameters. Three examples can be cited. First, the time of ozonation, as well as organic composition, is important in determining the quality of water and must be investigated in much greater depth. Second, the health implications of mutagenic activity or trace-level organics must be understood much better and even more sensitive and well defined analytical techniques may be required. Third, the design and reporting of experimental studies can have enhanced value when consideration is given to the potential removal mechanisms, such as biodegradation, volatilization, and sorption.

The direct applicability of the information to American practice is limited. The main restriction is that wastewater reclamation for potable use is unlikely to be allowed to the USA. Thus, much of the information must be somehow transferred to water treatment or to discharge of treated wastewater.

I. SESSION

- A. Day: Wednesday, June 25, 1980
Hall: B
Time: 2:00 pm to 4:15 pm
- B. Theme of Session: Fate of Chemical and Microbiological Constituents in Different Water Environments

II. REVIEWER

- A. Name: Michael C. Kavanaugh
- B. Position and Affiliation: Principal Engineer
James M. Montgomery
Consulting Engineers, Inc.

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 39: "Simultaneous in situ Determination of Dissolved Nitrogen and Oxygen by Gas Chromatography," L. M. Evison (UK) and E. Tosti (Italy).

The authors report on field and lab investigations of survival of E. Coli and faecal streptococci in sea water in the Bay of Naples. Measurements of these two bacteria were made on water and sediment samples at 21 shoreline sites during the month of August. The temperature and light sensitivity of the organisms were also studied in the laboratory. In-situ T₉₀ values were determined using a plexiglass container anchored in the bay.

Results indicate that E. Coli die more quickly when the temperature is less than 20°C. At higher water temperatures, T₉₀ values do not show statistically significant differences. Data were quite limited however.

New data not shown in the paper indicated that E. Coli is more light-sensitive than other potential indicator organisms including the enterococci and especially the pathogens such as Salmonella spp.

Authors conclude that faecal streptococci may be an improved indicator of bacterial pollution and of the possible presence of human pathogens. New concentration and isolation techniques used by the authors are claimed to overcome traditional reluctance to measure enterococci on a routine

basis.

N. Paul (UK), the assigned discussor, emphasized the many factors responsible for bacterial decay in sea water and questioned whether field tests were of sufficient extent and duration to warrant conclusions on causes of differing decay rates observed for the two bacteria studied. Surveys he was familiar with reported much higher ratios of E. Coli to faecal streptococci. The discussor was concerned that this ratio may not be of much value as a bacterial water quality indicator because of its variability and dependence on numerous environmental factors.

In floor discussion, Grabow (South Africa) questioned the terminology used by the authors and suggested that authors were measuring thermo-tolerant coliforms rather than only faecal streptococci.

Vial (France) stated that faecal streptococci have been used as the bacterial standard in sea water since 1960 in France. However, no bacterial regulations have been instituted in bathing areas based on faecal streptococci, because many Salmonella spp. have been found in waters devoid of the coliform group.

The author reemphasized the preliminary state of the conclusions and the need for more data.

- B. Paper No. 40: "Study of Partially Neutralized Aqueous Aluminum Chloride Solutions, Identification of Aluminum Species and Relation Between the Composition of the Solutions and their Efficiency as a Coagulant," J. Y. Bottero, J. E. Poirier, and F. Fiessinger (France).

The authors investigated the physico-chemical properties of monomeric and polymeric inorganic species present in concentrated aluminum chloride solutions prepared under varying degrees of neutralization and aging. Using NMR, Rayleigh diffusion and small-angle X-ray scattering, direct experimental evidence of an Al polymer containing 13 Al atoms is reported. The size of polymers formed ranged from 100 nm up to 5000 nm for gel-like aggregations of $Al(OH)_3$.

Batch coagulation tests using bentonite clay as the particulate indicated that a solution of $AlCl_3$ neutralized to give $r = (OH)/(Al) = 2.5$ and aged for 24 hr provided the most efficient turbidity removal. Authors propose that

properly prepared solutions of aluminum chloride, known as poly basic aluminum chloride (PBAC), are superior coagulants compared to metal salt solutions now used for coagulation in water and wastewater treatment applications in the USA.

The formal discussor, O'Melia (USA) appreciated the direct experimental evidence of the Al_{13} polymer (USA) but cautioned that the efficiency of a given coagulant is dependent on numerous factors. Thus, it is unlikely that a single inorganic coagulant specie would be optimum under all circumstances encountered. In flocculation experiments, authors added up to 30 mg/L as alum which more than doubled the floc volume in the batch reactors. It is likely that this may have been the cause of improved coagulation efficiency of neutralized $AlCl_3$ solutions.

In floor discussion, Stumm (Switzerland) also questioned the importance of Al_{13} polymer in practical applications. Chemistry of coagulation is complex and authors should not overinterpret results of lab studies.

Tambo (Japan) stated that over 80% of the water treatment plants in Japan (more than 1000 plants) use PAC (polyaluminum coagulant), a neutralized form of $Al_2(SO_4)_3 \cdot xH_2O$. The major reason was low alkalinity of most surface waters in Japan and low organic content of suspensions. His work also indicates that flocs formed with PAC have greater floc strength and density when compared with flocs from alum.

Fiessinger (France) agreed with discussors that coagulant chemistry is complex. He feels that $Al(OH)_3$ gel is the most important coagulant species. He compared PBAC with Japanese PAC and found very different removals, PBAC being superior.

- C. Paper No. 41: "Evaluation of Organic and Mineral Pollutants in Surface Water Under the Effect of Lagooning," F. Erb, J. Dequiol, A. Brice, J. l'Hopitau, A. Phillippe, and J. N. Pommeroy (France).

The authors evaluated the fate of numerous organic and inorganic constituents in an experimental, continuous-flow lagoon designed to simulate 30 days detention time of polluted surface waters prior to conventional water treatment. Organic constituents were measured by gas chromatography using both packed and capillary columns and HPLC. Hexane and chloroform extracts, as well as the closed loop stripping technique, were used to concentrate

different organic species. Metals were differentiated into three groups: free metals (FM), labile metal complexes (LM) and bound metal (BM).

The surface water which originated from the Lys River had a COD from 50-70 mg/L and a TDS of 575 mg/L. Removals of volatile organics (specific compounds not specified) was high but no quantitative data are given. Polycyclic aromatic hydrocarbons, organo-chlorine compounds, and phthalates showed varying degrees of removal, with accumulation in the sediments observed. No attempts were made to specify and evaluate the processes responsible for removal of organics.

Removals of total trace metals ranged from ten percent to 30% for Cu, Pb, Zn, Cd, Fe and Mn. Processes such as metal complexation by humic substances and subsequent adsorption on particulates appear to produce an attenuation of mean residence time of metals in lagoon. Authors recommend lagooning as a pretreatment step for control of organics prior to water treatment.

J. Smith (USA), an invited discussor, agreed that a lagoon is an effective equalization basin but questioned whether a lagoon provides a sufficiently efficient barrier for reduction of nonvolatile trace organics. He also expressed concern over algae growth in lagoons and possible release of toxic compounds from sediments. He did not consider 30 days detention time feasible in most industrialized nations due to land costs.

IV. CRITIQUE OF SESSION

Both Paper Nos. 39 and 41 summarized large-scale field investigations under variable environmental conditions. The papers were difficult to follow because they failed to report data from all sampling locations and because experiments were conducted without any explicit model of the system under study. In the case of Paper No. 39, sampling apparently was conducted over a two-month period only. This data base is insufficient to support abandonment of E. Coli as principal indicator organism of faecal pollution in the sea. This is a subject that has been studied extensively around the world, principally in the context of outfall design.

Paper No. 41 addressed an interesting topic which to this reviewer's knowledge has not been widely investigated. Lagoons are used for pretreatment of major surface supplies in London (Thames River) and Amsterdam (Muess River) and little data are available on pollutant transformations in these systems.

The paper, however, does not satisfy standard criteria for completeness of such field investigations. No attempts were made to complete mass balances on any constituents, even conservative components, to validate the sampling procedures. Problems of quality variability with various factors notably temperature, and the impact of these factors on removal were also not addressed. While providing some potentially useful semi-quantitative data on the performance of lagoons, the authors have not provided convincing evidence that lagoons could supersede other treatment processes such as air stripping or activated carbon as barriers to organic contamination of drinking water.

The principal conclusion of Paper No. 40, that PBAC is a superior to other metal salts, may not be supported by the data presented.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Some workers active in the areas addressed by Paper Nos. 39 and 41 may wish to contact the authors to obtain more useful data than are given in the papers. Paper No. 40 advocates the use of a new inorganic coagulant to replace metal salt solutions such as alum or ferric chloride. As always, the choice of a coagulant will be based on efficiency, cost, sludge handling and chemical storage requirements. It seems unlikely that PBAC will find much use in wastewater treatment because of cost, chemical storage, and uncertain claims of superior efficiency.

I. SESSION

- A. Day: Thursday, June 26, 1980
Hall: B
Time: 9:30 am to 12:30 pm
- B. Theme of Session: Industrial Wastewater Treatment

II. REVIEWER

- A. Name: K. Daniel Linstedt
- B. Position and Affiliation: Professor of Sanitary Engineering, Department of Civil, Environmental, & Architectural Engineering, University of Colorado Boulder, CO

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 42: "Activated Carbon Processes for the Treatment of Chromium (VI) - Containing Industrial Wastewaters,"
A. R. Bowers and C. P. Huang (USA)

This paper reported on a laboratory evaluation of several contacting systems for the removal of chromium (VI) from synthetic wastewaters on activated carbon. Completely-mixed, column, and rotating carbon disk systems were compared as system design alternatives. The influence of controllable parameters such as pH, Cr(VI) concentration, column depth, and mixing in solution were evaluated for the possibility of scale-up to an economically feasible treatment system.

Removal of hexavalent chromium from industrial wastewaters by adsorption on activated carbon has been shown to have some promise. Unfortunately, Cr(VI) is reduced rapidly to Cr(III) in the presence of activated carbon. The authors evaluated several reactor configurations on a bench scale to identify the reaction conditions which maximized Cr(VI) adsorption while minimizing the reduction reaction.

In complete mix reactors, the Cr(VI) $\rightarrow$ Cr(III) reduction was found to occur very rapidly at the low pH conditions which are most favorable for Cr(VI) adsorption. Further, the reduction rate was enhanced by increased velocity gradients within the reactor.

Packed bed column contractors were recognized as having several inherent advantages in that they are simple to operate and the concentration gradient in these systems provides a more economical use of the carbon through a higher packing density of Cr(VI) onto the carbon surface. Unfortunately, there is virtually no means of controlling the reduction reaction in packed beds with the result that the authors observed approximately 25% Cr(VI) $\rightarrow$ Cr(III) reduction in their pilot column tests.

To circumvent the shortcomings of the complete-mix and packed bed reactors, the authors developed a rotating disk contacting system in which the carbon was attached to rotating disks submerged in a mixed reactor. Advantages cited for this reactor were that it provided a concentration gradient, no carbon separation was required, pH control could be provided to minimize chromium reduction, and it allowed for inclusion of different types of carbon in the last disk sections to absorb any Cr(III) which might be formed.

In order for this system to be effective for total Cr removal, it was found that some type of adsorbent was needed to effect removal of Cr(III) which formed in the early stages of the reactor. Initial screening evaluations showed the best carbons tested to provide only 17.5% Cr(III) removal in batch tests. Current work underway is directed at developing a pelletized powdered carbon in an effort to improve the Cr(III) removal capabilities of this system.

The invited discussor, Hart (South Africa), initiated the discussion by noting that the motivation for this work was apparently related to the need for an efficient and economical Cr removal and recovery process for treatment of industrial wastewaters. In view of this motivation, Hart questioned why no mention had been made of conventional processes for treating metal plating wastes and what the advantages of the activated carbon process were over these processes. In fact, it was noted that one of the conclusions in the paper stated that removal of Cr(VI) by activated carbon is a complicated process. Hart identified this as a major disadvantage, and inquired about a number of other practical aspects of the process as follows: (1) Hart asked why Cr(VI) should not be purposely reduced to Cr(III) with some subsequent simple process developed to remove only Cr(III); and (2) In view of the fact that chromium would normally exist in plating wastes with other metals and organics, Hart expressed concern that no work had been performed which considered the presence of these other competing species; (3) Since the recovery of chromium

appeared to be a significant factor in the overall process economics, Hart asked if the authors had investigated any specific methods of chromium recovery. Further, Hart expressed doubts about the economics of the system in view of the very large carbon inventory requirements.

In an earlier paper by Huang, it was stated that the adsorption of Cr(VI) exhibited a maximum capacity in the pH range of five-six. In the present work, the results of batch experiments showed the maximum Cr(VI) adsorptive capacity to occur at pH 2.5. Hart questioned the apparent discrepancy. Concern was expressed with regard to the small size of the carbon contacting system and the fact that contact time and wall effects may be severely distorted in reactors containing only 10-30 g of carbon. Hart questioned why the reduction of Cr(VI) to Cr(III) occurred only on the surface of the carbon and not after the chromium had moved into the carbon pore structure.

In floor discussion Masschelein (Belgium) questioned why a vertical column containing several replaceable stationary disks could not be used in place of the rotating disks.

Hart (South Africa) again raised the question of system costs by asking whether the costs included any provision for pretreatment of grease-laden waters ahead of the reactors or for the costs of returning the chromium to the useful Cr(VI) form.

Dore (France) asked whether comparative studies had been performed with anionic resins which should also provide potential for Cr(VI) recovery.

Bowers, the author, cited the following advantages for the carbon adsorption process over conventional reduction and precipitation: (1) carbon adsorption provides a better opportunity for direct recovery of Cr(VI); (2) activated carbon provides a cleaner Cr(VI) solution because grease is retained on the carbon during regeneration; (3) if reduction to Cr(III) were desired, activated carbon would provide this reduction less expensively than bisulfate or other reducing chemicals.

The earlier work indicating peak adsorption at pH five-six was based on the assumption that adsorption equilibrium was achieved in 24 hr. Subsequent work has shown that the experiment must be terminated earlier to avoid reduction of all the chromium to Cr(III). Thus, the apparent adsorption peak at pH five-six was actually in error, and lower pH levels maximize the adsorptive capacity on the carbon surface.

Bowers noted that the mixing rate does not affect the adsorption process although it does affect the rate of reduction very significantly. Rotational speed in the disk reactor would be controlled to retard the reduction in an effort to achieve the maximum adsorption without having the trivalent species produced. Further, rotation provides continual resuspension of particulates and minimizes clogging which might occur as a result of Cr(III) precipitation.

The observation that reduction only occurs at the particle surface was supported by noting that the ratio of reduction to adsorption varied with carbon particle size. For smaller particle sizes, the Cr(VI) reduction rate always increased in proportion to the external surface area. Bowers cited the unavailability of sufficient protons within the internal micropore structure as an explanation of why reduction is limited in the internal carbon structure.

In response to Hart's question regarding system costs, it was indicated that costs of pretreatment and Cr(VI) recovery had not been included because the value of the recovered Cr(VI) would offset these aspects of the recovery phase. Relative costs were developed simply as a means of comparing different reactor configurations.

Finally, Bowers indicated that he had not investigated any anion exchange resins for Cr(VI) removal and recovery. However, he did not note that others had made such an evaluation with somewhat conflicting results regarding the physical attrition of the resins under the severe oxidizing and pH conditions of the chromium waste. While Bowers chose carbon for study because of its comparatively low cost, he did feel that a comparison should be made with anion exchange resins.

- B. Paper No. 43: "The Removal of Nitrogen from an Inorganic Industrial Effluent by Means of Intensive Algal Culture,"
F. Hendricks, J. Bosman (South Africa)

The feasibility of algal mass culture as a means of removing nitrogen from an inorganic nitrogenous effluent was investigated. It was shown that nitrogen concentrations of 100 mg/L can be removed from water by a multistage algal process. Important design parameters for this process have been evaluated with residence time identified as the most important design parameter. This parameter was dictated by the nitrogen removal rate and the algal productivity which was a function of the incident light and temperature. The growth characteristics of the predominant organism, Ankistrodesmus, were defined and compared with those found by other workers.

The primary objective of the algal treatment system reported in this paper was to provide economical removal of nitrogen from an industrial wastewater containing approximately 50 mg/L $\text{NH}_4\text{-N}$ and 50 mg/L $\text{NO}_3\text{-N}$. In this situation, the limiting algal growth factors were identified to be light and temperature. The algal concentration and depth always appeared as a product in the growth rate relationships which lead the authors to develop a new term to define the areal algal concentration. This term allowed for generalizing experimental results and expressing productivity independent of depth. The productivity ($\text{g/m}^2/\text{day}$) was shown to be constant over a broad range of areal algal concentrations for both summer and winter conditions, prior to dropping very sharply at a critical areal algal concentration. Nitrogen removal productivity curves were used to evaluate various pond systems for treating the industrial wastewater of interest.

One system evaluated was a single stage pond system followed by algae harvesting. In this completely mixed system, removal of substantial quantities of nitrogen dictated a shallow pond depth. Such a system posed practical problems from the standpoint of difficulty of construction and thermal instability. To circumvent the thermal instability problem, a reduced surface to volume ratio was provided in a second configuration involving multistage treatment with harvesting between stages. Operation of this system showed that $\text{NH}_4\text{-N}$ was preferentially removed to a residual $\text{NH}_4\text{-N}$ concentration of about ten mg/L, at which point $\text{NO}_3\text{-N}$ uptake began. While this system was shown to be stable, it was expensive to operate because of the number of harvesting stages.

A third configuration test involved a multistage system with decreasing pond depths. The depth reduction served to maintain the areal algal concentration in each stage and reduced the required number of harvesting stages. This system was thermally stable and provided the greatest operational flexibility. Operation of the decreasing depth system with a 0.5-m deep pond followed by a 0.25-m deep pond showed $\text{NH}_4\text{-N}$ reductions from 45 mg/L in the feed to 25 mg/L after the first stage and to less than ten mg/L after the second stage. By increasing residence times, it was actually possible to reduce the effluent concentration to near zero.

R. Stevens (UK), the assigned discussor, noted that the presence of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in approximately equal concentrations may pose a problem where total nitrogen removal is desired because of the preferential way in which algae utilize $\text{NH}_4\text{-N}$. As such, the practical potential of

the algal culture system for total nitrogen removal should be compared with other nitrogen removal systems which are technically and economically viable at the present time.

Three specific points were raised regarding the technical content of the paper: (1) in the batch culture experiments, why was the growth rate linear rather than exponential through the first ten days if light was not limiting, (2) was the quality of the protein recovered in the algae high in nutritional value and digestability, and (3) did the addition of phosphorus to the system result in any phosphorus discharge in the effluent which would have an adverse impact on the downstream receiving water?

In floor discussion Montalvo (Cuba) noted that the addition of phosphorus in the system introduced a substantial cost component to the process. He questioned whether it would be feasible to add municipal wastewater as an alternative phosphorus source.

Hendricks (USA) replied that in the multiple stage decreasing depth system, the sequential removal of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ poses no problem since all the $\text{NH}_4\text{-N}$ can be removed in the first stage and the $\text{NO}_3\text{-N}$ in a subsequent stage. With regard to light limitation in the batch culture system, it should be noted that these experiments were conducted in the field where there was a cyclic variation of light intensity throughout the day. In the early morning and late afternoon the system was light limited while over a short period in the middle of the day, it was not light limited. The net result of these variations was a linear growth rate relationship.

The protein content of the Ankistrodesmus was determined to be as high as 58% on a crude gross basis. However, the digestability is likely a problem with all fresh water algae because the nature of the cell wall retards digestability.

The phosphorus was actually added on a stoichiometric basis so that all phosphorus was removed in the final stage of the ammonium system. Domestic wastewater certainly could be used as an alternate source of phosphorus although all of the phosphorus requirement would probably not be satisfied by this source because there would be a contribution of nitrogen also. In the treatment situation under consideration, the waste had a low organic carbon content which the authors wanted to maintain so as not to change the predominant algal species.

- C. Paper No. 44: "Biological Nitrogen Control of Coke Plant Wastewaters," T. R. Bridle, W. K. Bedford, and B. E. Jank (Canada)

Bench-scale studies were conducted to evaluate the efficiency of the pre-denitrification/nitrification flowsheet for the treatment of coke plant wastewaters. Wastewater used in the study was comprised of limed ammonia still effluent and light oil interceptor wastewater obtained from Dominion Foundries and Steel Limited, Hamilton, Ontario.

At anoxic and aerobic hydraulic retention times of one and three days, respectively, complete nitrification and denitrification was achieved provided dilution at 4:1 was practiced or powdered activated carbon was added to the feed. The minimum aerobic SRT required to achieve complete nitrification of the diluted wastewater at 22 to 24°C was 22 days.

The organic carbon present in the wastewater can be used as the energy source and electron donor for the denitrification reaction. This study showed that no supplemental organic carbon is required to achieve complete denitrification provided the FOC/TN ratio in the feed is greater than 3.5.

While many steel mills employ biological processes to oxidize the phenolics, sulfides, thiocyanates, and cyanides in coke plant wastes, few plants currently exercise nitrogen control. This project was undertaken with the objective of developing and optimizing a biological process to effect a complete nitrogen control of these wastewaters. The process configuration evaluated was a single sludge pre-denitrification/nitrification system which was selected for its potential cost effectiveness.

The reactor sequence consisted of a first stage complete mix anoxic reactor followed by a second stage aerobic reactor. Mixed liquor recycle was achieved by recycling sludge from the clarifier to the first stage reactor at a recycle ratio of 8:1. The hydraulic retention time (HRT) was controlled at a nominal one day in the anoxic reactor and three days in the aerobic reactor based on the feed rate. The experimental program was divided into two phases: (1) the first phase employed a diluted mill wastewater feed to maintain influent ammonia levels of less than 100 mg/L; and (2) the second phase involved utilization of undiluted wastewater which had received pretreatment within the steel mill.

Results of the Phase I study revealed that complete

nitrification and denitrification could be achieved at 22-24°C provided the system solids retention time (SRT) was maintained in excess of 30 days — eight days anoxic SRT, and 22 days aerobic SRT. However, the lack of $\text{NO}_3\text{-N}$ in the effluent indicated inhibition of Nitrobacter. No supplemental carbon was required for denitrification provided the ratio of filtered organic carbon to total nitrogen was in excess of 3.5 in the feed. During Phase II, it was determined that nitrification could not be achieved at a system SRT of 40 days, presumably because of the presence of inhibitory organic materials present in the wastewater. As a result, powdered activated carbon (PAC) was added to certain of the reactors. With PAC in the system, it was possible to achieve complete nitrification of the mill wastewater.

The assigned discussor, Bulani (Canada), opened the discussion by drawing attention to the high inorganic content of the MLSS in this study, probably associated with the presence of calcium phosphate which precipitated from the limed mill wastewater. He then questioned the criteria used in selecting the fixed net HRT levels of 2.66 and eight hr, respectively, for the anoxic and aerobic reactors.

In view of the fact that rather long SRT levels were imposed on the system, Bulani asked how the system would have performed: (1) if the HRT levels were reduced by increasing the wastewater feed rate while keeping the recycle ratio at 8:1 and (2) if the HRT levels were held at the initial values by increasing the wastewater feed rate while decreasing the recycle ratio. In line with this, Bulani asked how a cascaded recycle might be implemented to reduce the microorganism acclimation requirements necessitated by the continual cycling between the anoxic and aerobic reactors.

Finally, a question was raised regarding the point of greatest benefit from the addition of PAC. Bulani asked whether the PAC was more readily coated with microorganisms in the anoxic or aerobic reactors. He suggested that observations of this type could reveal how best to selectively prefilter the chemicals which are toxic or hazardous to the microorganisms.

In floor discussion, Kruzins (Canada) asked whether the author still felt that PAC addition would be required in overcoming the nitrification inhibition in the wastewater studied. Further, he inquired as to whether phenol would be an adequate carbon source for the denitrification reaction or whether a supplementary source would be required.

Azkona (Spain) questioned the experimental conditions described by Fig. 5 in the text. If the operation

was steady state, it was not clear how the effluent nitrogen concentration was reduced with time. Additionally, Azkona inquired as to whether the authors had made analyses in the anoxic and aerobic reactors to ascertain which organic compounds were degraded in the anoxic system and which were degraded in the aerobic reactor. Finally, were growth rates and yield coefficients estimated for Nitrosomonas and Nitrobacter, and for COD removal?

Law (South Africa) pointed out that the high recycle taken from the clarifier would impose significant design limitations on a full-scale clarifier. He questioned why the recycle was not withdrawn before the clarifier.

Chen (USA) noted that the MLSS levels seemed quite low. He indicated that he had experience which demonstrated that by using PAC in the aeration unit at concentrations of about 10,000 mg/L, the MLVSS concentration could be maintained at about 8000 mg/L. He inquired about whether the HRT level could be reduced at the same SRT by increasing the MLSS concentration to two-three times the levels reported in this study. Additionally, he questioned why the data showed very little cyanide removal.

Neufeld (USA) noted that some substances which inhibited nitrification were apparently adsorbed on the PAC and not biologically degraded. He asked whether the authors had any data which showed the difference between the trace organics in the systems with PAC as opposed to those without PAC. He indicated that there may be some critical threshold of a key constituent or constituents above which there was a toxic impact on the nitrifying bacteria.

Bridle, the author, agreed with Bulani that in the treatment of limed coke plant wastewater, calcium phosphate is precipitated. He noted that this is a significant reaction since the phosphorus requirements are substantially increased. However, he stated that if caustic is used for pH elevation and removal of more of the ammonia, the precipitation can be overcome. In fact, the paper discussed a pretreatment system for removing calcium, which achieved a tenfold reduction in phosphorus requirements and a subsequent increase in the volatile solids fraction to about 80%.

The author responded to the questions related to HRT and SRT levels by stating that the initial HRT levels were selected after considering both theoretical and practical inputs. Design based on the unit rate approach for an MLVSS level of 3000 mg/L in the first reactor would dictate a feed HRT of 0.5 days for this wastewater. One day was used to provide some margin of safety. Likewise, review of the

literature and the experience at other steel mill operations indicated that only those plants with aerobic system HRT levels in excess of two days were achieving nitrification. As a result, the authors elected to start with a three-day HRT.

The minimum HRT requirements to achieve nitrification were determined in Phase I and these levels were equalled or exceeded in the subsequent operations of the system. Bridle noted that the recycle rate of 8:1 was selected to permit theoretical removal of approximately 90% of the total nitrogen entering the system. Phase III of the study was completed subsequent to writing the paper and focused on reducing the HRT levels by increasing the feed rate while holding the recycle at 8:1. Through this approach, the HRT levels were reduced to one half day in the anoxic reactor and one day in the aerobic reactor. In this mode complete denitrification was maintained, although nitrification was severely impaired and the operation was very unstable at the extreme case of one-day aerobic HRT.

At higher aerobic HRT levels of two-three days, the nitrification performance was excellent, with very little process variability. The recycle rate was not reduced since it was felt that this would have adversely affected the effluent total nitrogen and the costs of full-scale operation related to oxygen application and alkalinity requirements.

The author addressed the question regarding the impact on autotrophic organisms of anoxic-aerobic cycling by noting that previous work in both Canada and South Africa has shown that anoxic periods of five hr. or more had not adversely affected nitrifier performance. Since the cycle times in this work were below the indicated levels, Bridle felt that the process kinetics were not adversely impacted.

With respect to PAC, Bridle noted that only the organic carbon required for denitrification was utilized in the denitrification reactor. This implied that there was a substantial quantity of readily biodegradable or adsorbable organic carbon in that reactor which would likely be adsorbed there, although it would be difficult to isolate the location since the system was operated as a single sludge system. For the same reasons, it was difficult to isolate the reactor showing the greatest biological fouling of the PAC. However, close examination revealed a substantial variation in the extent of carbon surface fouling. Some carbon particles were completely enmeshed in the biomass while other carbon particles looked almost like virgin carbon.

Bridle indicated that prefiltering through granular

activated carbon (GAC) did not have economic merit in this system since it would diminish the organic carbon needed for denitrification, thereby significantly affecting the process costs.

In response to Kruzins, Bridle stated that he felt that PAC will be required in the single sludge pre-denitrification system for treating the wastewater which was investigated. However, this may not be a requirement in treating other coke plant wastewaters since there is evidence to indicate that other coke plant wastewaters contain different components. With respect to carbon sources for denitrification, mass balances around the system have shown phenol reduction in the anoxic stage indicating that it is utilized as a carbon source for denitrification. As such, for the wastewater investigated in this study, no supplementary carbon would be required to achieve denitrification if the necessary carbon-to-nitrogen ratio can be satisfied during all fluctuations in the coke plant operation.

In responding to Azkona, Bridle confirmed that the data used to develop Fig. 5 did represent an unsteady state. The oxidation rates were calculated after an upset in the continuous flow reactors, and were estimates of the rates achieved under those conditions. With regard to the concentrations of organics in the anoxic and aerobic reactors, it was stated that only filtered organic carbon and phenol determinations had been made. However, for these parameters there was a significant difference in concentration between the two reactors.

Bridle responded to Law and Chen by indicating that the authors had elected to achieve mixed liquor recycle by combining it with sludge recycle. This was done only as a matter of convenience in the small-scale experimentation. It was acknowledged that this would not be practical at full scale. With respect to the MLSS level in the reactor, Bridle noted that in recent work the authors have operated at levels similar to those discussed by Chen although lower levels of PAC were always maintained. With 500 mg/L PAC in the system, the total solids, including precipitated calcium phosphate, reached levels of 15-20,000 mg/L. Relative to cyanide removal, it was noted that both free and complex cyanide were measured in the total filtered cyanide determinations reported in this paper. Bridle speculated that the poor cyanide removals were probably the result of the presence of significant complexed cyanide in the wastewater which was neither adsorbed nor biodegraded in the system.

In responding to Neufeld, Bridle agreed that trace organics are probably the cause of the observed inhibition of

nitrification and that some threshold concentration dictates the presence of this inhibition. Extensive GC-MS work is currently underway to identify the compounds that are adsorbed and those that are biodegradable. This is being done with parallel treatment systems, one employing activated carbon and the other with no carbon.

- D. Paper No. 45: "Adsorption and Ion Exchange Processes for Treatment of White Water and Waste Water of Paper Mills," C. H. Möbius (Germany)

For ecologic and economic reasons it is necessary for paper mills in countries with a high population density to move toward a closed water system. This water recycling results in high concentrations of dissolved inorganic and organic substances which cause some difficulties in the paper making process. In particular, organic substances in the water adversely affect production and reduce product quality. Some of this organic matter is negatively charged and some is neutral. The negatively charged organics create the most severe problems in paper processing. For this reason, it was expected that adsorbents with a positive surface charge would show the best performance in reducing both the color and COD. However, the laboratory tests showed that it is necessary to consider the specific surface, the pore diameter distribution, and the surface energy to identify the best adsorbents. Very good results were obtained with macroporous anion exchangers with cellulose based ion exchangers more cost-effective than resins.

Paper mills started some time ago to partially reuse the white water discharged from the paper machine. This reuse was initially motivated by economic considerations. The result has been that the average specific fresh water need for paper mills has been reduced from 600-800 m³/ton at the beginning of this century to above 50 m³/ton at the present. In fact, in some cases it is possible to close the circuit totally so that no wastewater is discharged. Accompanying the reduction in fresh water consumption, the total organic waste discharge is reduced even though the concentration may be increased. However, because of the increased concentrations of troublesome organics in the water circuit, there is a product specific limit for closing the circuit with the simple technology used today. As a result, there is an urgent need to develop new technologies allowing a further reduction of specific freshwater consumption, with the final goal of closing the system totally.

The intention of the research and development

project reported in this paper was to identify physical-chemical treatment processes for reducing the concentration of organic substances in white water and wastewater. The processes investigated included adsorption and ion exchange. In developing the adsorption process, finely divided pigment-like adsorbents were selected which could be added directly to the pulp. These materials would adsorb the organic materials of concern and remain with the adsorbed material in the paper. The loaded adsorbent could be reused as a filler in the final paper product so that no regeneration and no solid waste discharge would be required.

In this study, adsorbents were tested with different paper mill white waters by dosing one liter of water with ten g of adsorbent and providing a contact time of 30 min. The best results in all tests for white water and wastewater were achieved with SiO₂ type adsorbents. This finding did not correspond to the results obtained by the authors with different types of model adsorbent substances. As such, it was concluded that a suitable model substance for testing adsorbents was not identified.

Continuous flow ion exchange studies were performed using several ion exchange materials with a number of paper mill waters. It was shown in these studies that ion exchangers can be used in place of or in conjunction with biological processes to treat paper mill waters containing substantial organic loads. Following ion exchange treatment, the bio-degradability of a typical paper mill wastewater was found to be enhanced. However, when ion exchange was employed after biological treatment the final white water quality was much improved and the total treatment costs were reduced. In the latter configuration, the following constituent reductions were achieved:

	<u>Percentage Reductions</u>			
	<u>TOC</u>	<u>COD</u>	<u>BOD</u>	<u>LIGNIN</u>
Wood Pulping Water	85	92	63	99
White Water	88	90	79	99

It was indicated that when these results are translated to a full-scale plant size, it would be expected that 80% COD removal and 60% BOD removal could be achieved. Of course, larger scale work would be necessary to verify this, and to develop design and cost information. It was estimated from the current work that costs of \$0.5/kg COD removed might be possible. For a typical paper mill, this would amount to about \$0.2/m³.

J. Norman (Canada), in his formal discussion, commented on the need for an expanded description of the experimental procedures used in obtaining results in this study. Further, he questioned why the percentage BOD reductions were so much less than either the percentage COD or TOC reductions. The only explanation he could offer was that the adsorbers and ion exchangers were selective for the long chained compounds that were not degradable.

In floor discussion, Lagrega (USA) expressed concern about the bed fouling which would be expected with the high suspended solids levels which accompany the paper mill wastes. Coagulation-flocculation was suggested for minimizing this problem, and attention was called to the plant in Fitchburg, Massachusetts for a comparison of available technologies.

Möbius addressed the question of relative BOD/COD removals by noting that the processes used were physical-chemical processes rather than biological. In fact, the discharge requirements in Germany will be related to COD rather than BOD in the near future which was one of the major motivations for consideration of physical-chemical rather than biological processes.

With respect to the solids fouling problem, Möbius noted that operation of the column systems in an upflow mode tended to minimize these problems. However, he did suggest that biological treatment ahead of the columns is desirable to minimize the solids fouling problems. He agreed that many practical questions remain to be addressed prior to the full-scale application of this technology.

IV. CRITIQUE OF SESSION

The discussion of Paper No. 42 was quite lengthy, perhaps because of the focus of the paper on the very real problem of removing toxic substances from wastewater and the potential of activated carbon for effecting this removal. However, most of their discussion related to apparent shortcomings in the experimental methods or in the conclusions developed regarding the practicality of the carbon adsorption method. It was clear from the presentation and discussion that many questions remain to be answered before the proposed application of carbon adsorption will be of practical value.

Paper No. 43 addressed a significant problem in the removal of nitrogen from industrial effluents. The study seemed to be conducted in a thorough and logical manner, proceeding from a definition of theoretical considerations to

the establishment of design configurations for the implementation of the technology.

The subject of nitrogen control in industrial effluents was also addressed in Paper No. 44. In this case, there seemed to be a great deal of interest in the research findings. This may have been due to the fact that the pre-denitrification/nitrification treatment configuration has a much broader range of potential applications than the algal culture method of Paper No. 43. While the reported work was performed at a rather small scale, the encouraging results would warrant demonstration at a larger scale and, possibly, full-scale application.

In Paper No. 45 neither the experimental methods nor the research findings were clearly established. The investigation was conducted on a small scale and involved processes which appear to be of limited practical value when compared with other processes that have been reported for providing similar levels of treatment.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

With the increased focus on pretreatment of industrial wastewater in the USA, each of the topics discussed in this session could have potential applicability. While none of the reported investigations was conducted at a sufficiently large scale to permit direct implementation, some direction was provided for further research efforts in this country.

From the insight developed by Bowers and Huang, it appears that carbon adsorption should be considered for use in conjunction with more conventional methods of metal plating waste treatment. The carbon could serve to either recover a major portion of the Cr(VI) and reduce sludge quantities or to chemically reduce Cr(VI) to Cr(III) prior to complete chromium removal by precipitation. In both cases, the carbon would serve the added function of minimizing the grease content of the treated water.

With respect to nitrogen removal from industrial wastewaters, both the South African work and the Canadian work have merit. The algal culture research is continuing on a pilot scale in South Africa and should yield some meaningful design information in the near future. Because of the relatively limited applicability of this technology, expansion of the research effort in the USA is probably not warranted at this time. The work of Bridle and his co-workers does appear to have potential for rather

widespread application in the USA. As such, it would appear reasonable to develop design information for the denitrification/nitrification flow sequence on a somewhat larger scale than that evaluated by the authors.

I. SESSION

- A. Day: Thursday, June 25, 1980
Hall: B
Time: 2:00 am to 4:15 pm
- B. Theme of Session: Heavy Metals Control and Subarctic
Impoundment Problems for Water
Quality Management

II. REVIEWER

- A. Name: Thomas H. Goodgame
- B. Position and Affiliation: Director, Corporate
Environmental Control
Whirlpool Corporation
Benton Harbor, MI

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 46: "Inorganic Mercury-Bituminous Coal
Sorption Interaction in Water,"
M. P. Pandley and M. Chaudhuni (India)

The authors presented data on the sorption of inorganic mercury on bituminous coal in the laboratory with a view to generate a background for a coal-based process for mercury removal from water. Mercury sorption was temperature dependent (heat of sorption, 0.91 kcal/mole; activation energy, 8.39 kcal/mole) and reduced with rising pH as well as with chloride and calcium concentration. Batch sorption kinetics and equilibria were described by reversible first-order reaction equations and Freundlich isotherms, respectively.

Sorption kinetic data indicated a rapid interaction involving mercury species and the active sites on the external surface of the coal followed by intraparticle diffusion of mercury for further reaction. This was corroborated through a consideration of the sizes of the micro- and macro-pores of coal and the mercury species. Linear variation of sorption rate with the reciprocal of the second power of sorbent size and mercury sorption with half power of time provided further experimental evidence. Desorption and regeneration data of mercury-loaded coal indicted the ion-exchange nature of the sorption reaction apart from possible contribution of an even stronger interaction, e.g., hydrogen bonding or chemisorption. Involvement of a high activation energy also indicated such

interactions. IR spectra of the coal with and without sorbed mercury supported hydrogen bonding. On the basis of the surface functional groups of the coal indicated by IR spectra and available information on reactions between mercury and the functional groups, possible specific chemical interactions are listed.

In the absence of the invited discussor, Stook (Spain), initiated the floor discussion by indicating that this might be a simple method of explaining some of what was going on - that is, hydrogen bonding was not necessarily the case. He suggested that there might be some amino groups involved or oxygen donor groups plus hydrogen ions.

A. Benedek (Canada) asked if there had been any attempt made to find out if the mercury on the coal was present partially or totally in the metallic state. He also questioned the establishment of actual equilibrium in as short a time as 24 hr.

The response to the first question was that metallic mercury had not been sought. The author also indicated that tests of only 48 hr had been run to determine equilibrium but that there had never been any change beyond 24 hr, so, equilibrium had been assured.

A. Powers (USA) brought up one controversial point in the discussion. He said that there were no known cases of endothermic adsorption, yet this was reported in this paper. He inquired if the result might not be due to some other phenomenon such as sulfide formation. The author indicated that they had found no effect of sulfur content of the coal. Otherwise they had no data to answer this problem. There was some further discussion of this point but no conclusion was reached.

Another question had to do with the comparability of coal with activated carbon for mercury adsorption and, based on their work, the processes favored by the authors. As indicated in the paper, coal is only slightly less effective than carbon. No particular process was favored.

The final point of the discussion was probably the most important and dealt with the problem of mercury recovery and/or disposal. The commenter indicated that there were three plants in Canada that volatilized the mercury from the coal and recovered it by condensation and he asked if this were being done anywhere else as a regeneration technique. The author indicated that their only regeneration work had been that reported in the paper.

In his closing summary, Chaudhuri indicated that there was still much work to be done on this process. They do not have enough data on the mercury content of potable water supplies in India but they appear to be very low. Some of the future work will be on improving the adsorptive capacity of coal by methods such as air oxidation.

- B. Paper No. 47: "Water Quality Changes and Clearing Requirements for Impoundments in Arctic and Subarctic Regions"
D. W. Smith (Canada) (Presented by Professor Brody)

The use of impoundments to store domestic water supplies in arctic and subarctic regions has been limited due to low population, lack of water distribution systems, technical problems with construction on permafrost and high construction costs. Many of these factors are changing and the need for impoundments is increasing. The subject of water quality changes in potential impoundments during winter periods was investigated through the use of static water leaching columns. The investigation procedure required the collection of soil samples from various depths and water quality monitoring over 1.75 months. Preliminary impoundment site clearing recommendations were made based upon the water quality changes observed during the laboratory tests. A proposed method of evaluation was presented.

The primary parameters for control are "color" and "iron content". Data were reported on a number of other parameters considered of importance, e.g., manganese, dissolved oxygen, ammonia, and tannin and lignin, but the two primary parameters appear to act satisfactorily as surrogates for the others.

The appointed discussor, P. Odendaal (South Africa), first asked why was the water sample taken directly above the soil surface? Second, why wasn't local stream water used instead of deionized water? Brody responded that in winter the impoundments may be frozen to a depth of several meters, so the water must be taken from deep in the reservoir, thus, the decision to take the samples near the soil/water interface was made. On the second point, deionized water was used to make the results more generally applicable.

- C. Paper No. 48: "Heavy Metals in the Ruhr River and their Budget in the Catchment Area",
Klaus R. Imhoff, Paul Koppe, and
Friedrich Dietz, (Federal Republic of Germany)

Numerous analyses of heavy metals have been evaluated with respect to origin, concentration, behavior and fate in the 4,488 km² catchment area of the most intensively used Ruhr River.

For the ratio of the dissolved and the total heavy metal concentration in Ruhr water, the following topological progression with increasing dissolved fraction results:
lead < copper < zinc < nickel < chromium < cadmium.

A heavy metal balance has demonstrated that 55% of the heavy metals in the Ruhr River are discharged from municipal and industrial wastewater treatment plants while 45% are of geochemical origin. The municipal treatment plants receive 31% of the heavy metals from domestic wastewater and 69% from industrial wastewater. These figures represent the average of all analyzed heavy metals. The fraction of the particular elements varies considerable. For example, 90% of the chromium, 65% of nickel and cadmium and 50% of copper and zinc are discharged by industries. The "population equivalent" of heavy metals was calculated from the results of 19 plants receiving only domestic wastewater deducting the fraction contained in the drinking water. About 40% of the total heavy metal load of the Ruhr River is deposited in the sediments of four impounding lakes in the middle and the lower Ruhr.

A topological progression for the relationship between heavy metal concentration in sediments and decrease of metal concentration in river water is similar to the one above. This indicates the decreasing fixation of metals in the sediment. Most of the industrial sources are either steel pickling or some 300 plating operations. Some of the industrial wastewater is treated before discharge but much of it is not.

R. Sanks (USA), the invited discussor, commented on the use of the "Woodruff" furnace as a part of the atomic absorption system to improve the ease of operations of the system.

Of particular interest in the floor discussion was the substantial non-industrial contribution of heavy metals load. It appears that the portion of the load has increased between four and seven fold over the last 40 years.

There are major unsolved problems which this study high-lighted. First, as noted above, control of industrial sources would reduce the heavy metal load but would not necessarily solve the problems because of the importance of non-industrial sources. The primary problem is how to

dispose of solids created in the Ruhr River Basin. These solids include the solids produced in the wastewater treatment plants and the sediments which accumulate in the catchment basin of the Ruhr River Basin. At present, only about ten percent of the municipal wastewater treatment plant solids can be used for agricultural purposes. This has dropped from about 50% a few years ago.

In summarizing his answers to questions and discussions, Imhoff pointed out that the increased use of chelating agents could cause the release of heavy metals from the sediments. He also suggested that there were cases where control of industrial sources did provide the answer to excessive heavy metal loads. Industrial control of cadmium had worked in the Munich area.

IV. CRITIQUE OF SESSION

Paper No. 46 dealing with the adsorption-desorption of mercury on coal really produced more questions than answers. There are very little data on mercury in water sources in India and where data are available, indications are that the mercury content is extremely low. Another unanswered question is for disposal and/or recovery of the mercury. Apparently there is some activity in this area. Vaporization and condensation would appear to be an area for serious future consideration. Finally, there was little indication as to the effect of other ions and anions on the usefulness of this media with the exception of limited work on the effect of concentrations of calcium and chloride ions and of pH.

Paper No. 48 gave answers to water pollution control problems specific to the Ruhr River Basin. It showed how data could be developed to provide for the solution of heavy metals in an entire river basin. There is much more effort needed in this area in the USA.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 46 on inorganic mercury adsorption by coal from water had little significance for American water pollution research. As the author pointed out, this was research primarily pointed toward supplying an inexpensive medium for use in underdeveloped countries.

Paper No. 47 dealt with potable water quality, storage and improvement problems in arctic regions. The applicability of this paper to American water pollution research is limited to the northern portions of Alaska and Canada.

Paper No. 48 dealt with the heavy metals material balance for an entire river basin. Although this long-term research provided answers specific to the Ruhr River Basin, it does show how the work should be done and points out problems for which solutions are needed. This paper also attempts to put into perspective which methods might be solutions to the problem of sludge contamination with heavy metals. This problem was much in evidence at the Stockholm IAWPR Conference in 1978. The authors indicated that their data indicated that pretreatment of all industrial discharges was not the solution to sludge utilization for agricultural purposes in Ruhr River Basin. It would appear from a study of these data that the problem could still be improved substantially by the requirement for pretreatment of all industrial wastes containing heavy metals. If this were done, the reduction of heavy metals in both the sludge and the water discharged would be reduced by the removal of that fraction of the 55% total load which comes from industrial wastewater that is not pretreated. Work of this sort on industrialized river basins in the USA would strongly support the present USA pretreatment program.

I. SESSION

A. Day: Monday, June 23, 1980
Hall: C
Time: 2:00 pm to 4:15 pm

B. Theme of Session: Modelling of Lakes

II. REVIEWER

A. Name: Charles R. O'Melia

B. Position and Affiliation: Professor of Environmental
Sciences and Engineering
Depart. of Environmental
Sciences and Engineering
University of North
Carolina
Chapel Hill, NC

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 49: "Transport of Heat and Nutrients
Across a Thermocline,"
P. J. de Bruijn, L. Lijklema, and
G. van Straten (Netherlands)

Modelling of water quality in lakes can involve analysis of the transport of substances within the lake waters and, in particular, the vertical transport of materials across the thermocline region during stratification periods. This is commonly accomplished by determining a vertical diffusivity coefficient from analysis of observed temperature data varying in space (depth) and with time. The procedure is termed "the flux gradient method". The authors note that two different physical transport processes contribute to the vertical transport of heat and mass in lakes, viz., wind-induced entrainment or erosion of upper hypolimnetic waters and diffusive transport.

The authors demonstrate that use of the flux gradient method for determining vertical diffusivities leads to erroneously high estimates of vertical diffusion in Lake Grevelingen in the Netherlands, develop a procedure for assessing the separate contributions of entrainment and diffusion to vertical mass transport, provide estimates of vertical mass fluxes of manganese, ammonia, silica, and phosphorus by these processes, and use available theoretical relationships to analyze their results for vertical turbulent diffusion. The paper was presented by L. Lijklema of the Netherlands.

The formal discussion was given by Benedict (USA). He focused on the relationships given by the authors between the vertical eddy diffusion coefficient (K^*_z), and the density gradient (dp/dz) or the Brunt-Vaaisela frequency (N). He noted that some empirical results in USA reservoirs show K^*_z proportional to $(1/N^2)^{0.7}$; others indicate relationships ranging from $(1/N^2)^{0.4}$ to $(1/N^2)^{0.9}$, depending on such factors as reservoir size and river flow rate. Noting that the authors indicate K^*_z proportional to $(1/N^2)^{0.73}$, Benedict asked for some explanation and interpretation of this portion of the author's work. He also congratulated the authors for a good attempt to separate advective behavior from diffusion coefficients in considering vertical transport in lakes.

In his reply, Lijklema noted that turbulence can be generated externally and internally. In the first case, large eddies are produced which decay to smaller ones; under these circumstances K^*_z is proportional to $(1/N^2)^{1.0}$. This is typical of epilimnetic processes. In the second case, turbulence is generated by local shear and is proportional to $(1/N^2)^{0.5}$. This may be representative of hypolimnetic waters. The empirical relationship for the thermocline determined by the authors [K^*_z proportional to $(1/N^2)^{0.73}$] may result from a mixture of these two physical processes.

One additional question was raised when discussion was opened to the audience. It was noted that the work of Jassby and Powell (Limnology and Oceanography, 20, 530) indicated that solar radiation had very significant effects on vertical transport in Castle Lake, in contrast to the conclusion by the authors that it was negligible in their study of Lake Grevelingen. In his reply, Lijklema noted that the waters of Lake Grevelingen have a very high extinction coefficient, so that direct solar heat does not reach the thermocline region.

- B. Paper No. 50: "The Impact of Sewers on the Nutrient Budget of Lake George, NY" by D. B. Aulenbach, N. L. Clesceri, and J. R. Mitchell (USA).

The authors present a budget for the nitrogen and phosphorus inputs to the South Lake of Lake George for presettlement conditions, present circumstances, and future conditions in which a sewage collection, treatment, and diversion system would be installed. Nutrient inputs from stream and urban runoff, direct wet and dry fall precipitation on the lake surface, and lawn fertilizer usage are evaluated for these three situations. The authors conclude

that the lake is now and will continue to be limited by phosphorus. Based on their assessment of nutrient inputs and Vollenweider's classifications of eutrophication, the authors conclude that the proposed sewerage, treatment, and diversion facilities will result in an increased phosphorus input to the lake and thereby contribute to increased eutrophication of this scenic natural resource. The paper was presented by D. B. Aulenbach.

The formal discussion was given by L. H. James (South Africa). He congratulated the authors on their systematic approach to identify, quantify, and compare nutrient sources, described similar problems and observations in South Africa, and asked for some clarifications regarding the nutrient budget developed by the authors.

With regard to eutrophication in South Africa, James noted that 98 bioassays indicated phosphorus to be the limiting nutrient in all oligotrophic lakes, and nitrogen to be limiting in lakes that had deteriorated to the hypereutrophic state, in agreement with the shift postulated by J. Vallentyne. Control of eutrophication by nitrogen removal was considered to be inappropriate for several reasons including diffuse, non-point sources of that element. He concurred with the conclusions of the authors that the system of sewage collection, treatment, and diversion proposed for Lake George would not succeed in halting eutrophication of the lake.

With regard to the specific budgets of nutrients made by the authors, James asked for clarifications about (1) the assumption that nutrient inputs from atmospheric sources would not increase in the future, (2) the possibility of nitrogen fixation by algae in the lake, and (3) the possible significance of the sediments as a source of phosphorus.

In conclusion, James indicated that in South Africa, nutrient inputs to lakes resulting from urbanization are controlled by land use restrictions (e.g., no resort buildings can be constructed within a specified distance of a shoreline) and by sewerage regulations (e.g., no toilets or septic tanks may be constructed below expected flood levels), and boating license procedures.

The author's responses were given by D. Aulenbach and N. Clesceri. The assumption that atmospheric inputs of nutrients to the lake would remain constant in future years was based on expectations that man-induced inputs would be small and also subject to source control. Nitrogen fixation was neglected because blue green algae are not common in the lake and because of the present and expected future

limitation by phosphorus. The sediments were not considered to be a significant source for phosphorus because the hypolimnetic waters are oxic at present and are expected to remain so under projected future nutrient loadings. Furthermore, there are indications that bacteria in the surface sediments are limited by phosphorus, and that P is retained in the sediments. Finally, the authors indicated that restrictions on resort development and septic tank construction can have only partial application for Lake George because of the extensive development already in place.

During the floor discussion it was confirmed (discusser from Zimbabwe) that sediments act as a sink for phosphorus. Questions were asked about (1) the biological availability of phosphorus reaching the lake in dry fall by atmospheric deposition, (2) the possibility that the lake embayments act as a seed providing organisms to the main body of the lake and, in particular, that turbid waters in the embayments could provide conditions suitable for *Volvox* which may subsequently enter the main body, (3) the possibility that seasonal changes and internal nutrient cycling may invalidate the results of nutrient budgets formulated on an annual basis, (4) possible development of anoxic bottom waters in the future, and (5) the accuracy of the dry fallout measurements made by the authors on land and their applicability to actual deposition in the middle of the lake.

The authors' replies are as follows: (1) data are not available on the biological availability of nutrients in the dry fall; (2) *Volvox* was observed to be a problem only once in the past. Algae in the embayments probably do not affect the main body of the lake significantly; (3) modelling of kinetic seasonal effects and internal nutrient cycling was attempted. The hydraulic detention time in the South Lake is about eight years, suggesting that annual loadings can be useful. The nutrient budget approach was adopted for simplicity; (4) anoxic hypolimnetic waters are not anticipated; (5) the measurements of fallout were made on a building and not on the ground. A location on the lake surface would have been better. It was assumed that measurements at the building simulated fallout on the lake.

- C. Paper No. 51: "Nonpoint Quantification and its Role in Lake and Stream Water Quality Planning," by R. Ahmed and R. Schiller (USA).

The authors have developed a simple model for quantification of nonpoint sources of pollution. The model includes: (a) runoff from urban areas, (b) erosion from other areas, (c) runoff from barnyards, (d) leachate from

landfills, (e) runoff from roads, (f) leachate from septic system fields, and (g) wet and dry fallout. The pollutants considered in the model include BOD, suspended solids, phosphorus, nitrogen, coliforms, oil and grease, heavy metals, and others.

The authors have verified their model by considering the phosphorus loading to Lake Waramaug in Connecticut. Estimates of phosphorus inputs based on their model are compared with field measurements and with the phosphorus model of Dillon and Rigler (J. Fisheries Research Board of Canada, Vol. 11, 1975). Agreement among the three estimates appears to be good.

Finally, the authors propose an application of their model to the planning of nonpoint source pollution control in watersheds. In this approach, annual loadings are used to identify "major" nonpoint sources of pollution. "Moderate" and "minor" problems are evaluated using selected summer flow and loading conditions. The objective of the model is problem identification. Site-specific abatement programs require additional detail including field studies. The paper was presented by R. Ahmed.

The formal discussion was given by Desbordes (France). He asked the following questions: (1) for several pollutants and for several sources, the authors determined an annual load by multiplying a selected constant times the rainfall. The discussor questioned this approach and suggested the use of an annual emission factor for each land use; (2) in analyzing pollutant runoff from feed lots, an average concentration in feed lot runoff is used by the authors. The discussor suggested the use of an average pollutant flux per animal as a more desirable alternative; (3) variations in runoff quality and flux are great when comparisons are made between sites, and even within a given site. The discussor requested information about the effects of such variations on the validity of the model results; (4) the discussor inquired about the minimum amount of data needed to use the model successfully; (5) the discussor noted that for some pollutants (e.g., nitrates as observed in France), the maximum concentration coincides with the maximum flow, yielding very high pollutant mass fluxes at high flows. Desbordes considered that the approach using averages as adopted in the paper will seriously underestimate the magnitude of nonpoint source pollution in such cases.

In responding to these comments, Ahmed offered the following replies: (1) annual emission factors were not used because they change from place to place. The approach used in the model permits accommodation of the effects of

geographic and climatic variations; (2) a similar argument is used to defend the selection of average pollutant concentrations in feed lot runoff in place of per animal fluxes, i.e., flexibility to account for the effects of such variables as rainfall; (3) pollutant runoff is recognized to vary from site to site. The coefficients are developed for certain reasonably homogeneous regions. Other coefficients must be developed for other sites or regions. In this management model, annual loadings are simulated. Short term temporal changes are not predicted; (4) it is hoped that there are sufficient data to develop the model for some watersheds, and then extrapolate the results to similar regions; (5) the experiences using the model in Connecticut indicate that the highest pollutant concentrations occur in summer flows, so that the combination of high concentrations and high flows noted by the discussor may not be significant in the uses of the model that have been made by the authors.

One question was asked in the floor discussion. Can an estimate of uncertainty be made for the predictions of the model? Ahmed replied by noting that the determination of uncertainty was the subject of a forthcoming paper.

IV. CRITIQUE OF SESSION

The interest of the audience was greatest in Paper No. 50, due to the nature of the problem, the power and simplicity of the approach used by the authors, and the excellence of the oral presentation. There was fair interest in Paper No., 49, due primarily to good oral presentation and the conceptual value of the work. This paper was the most theoretical in the session, and required considerable modelling experience to perceive its potential practical value. Paper No. 51 was vague and lacked both conceptual development and significant demonstrated practical application. Interest in eutrophication as a water quality problem was considerable among representatives from Europe and South Africa; it may be greater in these areas of the world than in the USA at present.

Paper No. 49 has the soundest scientific base and contains new research of probable value for modelling the transport of pollutants in lakes. The authors could have improved their work by comparing their results with those obtained by others and discussing similarities and differences. The formal discussion by Benedict served this purpose for that portion of the paper dealing with eddy diffusivities.

The authors of Paper No. 50 presented a comprehensive nutrient budget for a valuable water resource.

The work serves as a valuable example of how to make such a budget properly and of some of the problems encountered in doing so. In my judgment the authors misapplied Vollenweider's models when interpreting their results. Vollenweider's empirical loading graphs can be used to predict eutrophication when phosphorus inputs are estimated on bases comparable to those used by Vollenweider in constructing his "models" or graphs. His approach is more useful than his results. I also consider that the authors are somewhat misleading in their discussion and conclusions about the future changes in the lake that can be expected to result solely from the sewage collection, treatment, and diversion plan under consideration. Future effects with the plan should be compared with future effects without the plan in addition to present conditions.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The following conclusions are suggested by the papers in this session and by discussion within the session and subsequent to it: (1) the use of vertical diffusion coefficients based on the transport of heat as described by the flux gradient method has limitations and should be used with caution. Improved methods of describing vertical mass transport are available — they require no additional data. There are needs for additional conceptual research in this area; (2) nutrient budgets are powerful, relatively simple, and essential tools in managing eutrophication problems. The importance of direct atmospheric inputs of nutrients and other pollutants to lakes can be great and measurements are needed. Significant problems still remain in modelling water quality in lakes for both steady and nonsteady states. Both new concepts and new data are needed; (3) nonpoint sources of pollution may be significant in many cases, but real documentation of their magnitude and their effects on water quality is sparse; (4) there is a worldwide interest in water quality modelling. Empirical nutrient loading models have been valuable in managing eutrophication but have important limitations. As attention shifts to new pollutants, the potential value of models which can incorporate significant physical, chemical, and biological processes into predictive models that are less empirical than present efforts becomes more apparent.

I. SESSION

- A. Day: Tuesday, June 24, 1980
Hall: C
Time: 9:00 am to 12:30 pm
- B. Theme of Session: Evaluation of Organism Removal from Wastewater Reclamation and Surface Waters

II. REVIEWER

- A. Name: Dale A. Carlson
- B. Position and Affiliation: Dean and Professor of Civil Engineering
College of Engineering
University of Washington
Seattle, WA

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 52: "Evaluation of Acid-Fast Bacteria, Candida albicans, Enteric Viruses and Conventional Indicators for Monitoring Wastewater Reclamation Systems," by W. O. K. Grabow, J. S. Burger, and E. M. Nupen (South Africa)

The authors studied acid-fast bacteria, coliforms, Candida albicans, Pseudomonas aeruginosa, total plate counts, fecal streptococci, coliphages, and enteric viruses to seek routine monitoring techniques for wastewater reclamation systems that were relatively economical, simple and practical and within the capability of many microbiology laboratories. Their paper deals with the elimination of microorganisms from an activated sludge effluent treated in the 4000 m³/d Stander experimental wastewater reclamation plant in Pretoria. Like the operation at Windhoek, the Stander plant is a multiple-barrier system. In this study ferric chloride was used instead of lime for primary clarification and ozonation instead of chlorination for intermediate disinfection.

C. albicans and acid-fast bacteria were included in the study because their behavior in advanced wastewater treatment processes had not been previously investigated. C. albicans is a waterborne pathogenic yeast proposed as a potential water quality indicator; some members of the acid fast group are waterborne pathogens.

The methods used indicated that reliable results were obtained for acid-fast bacteria using triplicate samples over a nine-day incubation period. The membrane filtration technique for the C. albicans provided easily identifiable colonies.

In a period of operation without post primary clarification chlorination, most organisms showed little or no reduction through secondary clarification, and the subsequent treatment processes could not deal satisfactorily with the large numbers of microorganisms. When ferric chloride clarification is used, post primary chlorination is an essential disinfection substitute for the high pH in lime treatment. The chlorination step did not produce chlorinated compounds in quantities sufficient to produce health hazards.

While ozonation proved particularly effective for the inactivation of enteric viruses and coliphages, it was necessary to maintain both chlorination and ozonation above specified limits to avoid the presence of undesirable organisms after final clarification.

Properties of the acid-fast bacteria made them excellent indicators for multiple barrier systems. Their numbers in the raw water intake exceeded those of most other organisms and they showed exceptional resistance to chlorination. Also they were able to multiply in the sand filters and activated carbon columns.

Based on their studies, the authors have proposed that a total plate count of less than 100 per one mL and the absence of acid-fast bacteria, P. aeruginosa, total coliforms, and coliphages from 100 mL samples of the final water and, preferably, two intermediate stages, are feasible limits with a wide safety margin for routine microbiological monitoring of established multiple-barrier reclamation systems. Their view is that the limits are rather stringent and conservative particularly with the acid-fast bacteria and that further research may prove that certain concessions are possible.

The authors further feel that use of these tests warrants the omission of additional information on the enteric viruses. Even though the enteric virus tests are important in research on wastewater reclamation, their exclusion is important because the tests are expensive, require sophisticated laboratory facilities and highly trained staff and may take several weeks to complete. For example, the costs for the enteric virus tests have been estimated to cost about 100 times more than the total plate count or the total coliform test. The difference in costs

emphasizes the value of finding routine monitoring such as the total plate count and total coliform tests that are relatively economical, simple, practical, and within the capability of many microbiological laboratories.

The formal discussion was presented by H. Shuval (Israel). He noted the important contribution of the authors to the development of monitoring for wastewater reclamation systems and their innovative concepts on nonconventional indicators. Since the recent WHO report on viruses in the water environment pointed out that the weakness of conventional fecal coliform indicators for evaluating the concentration of viruses was that they were less resistant, this work on acid-fast bacteria as more resistant indicators is very promising.

Shuval then addressed a number of comment concerning the paper. In the problems mentioned by Grabow on the limitation of various techniques, the length of time of the test was mentioned. The acid-fast bacteria test is also slow so it does not fully answer the length of time question, if three to five days are required for initial detection and up to ten days for final identification.

The second concern was in regard to the one-month period when chlorination was not practiced and the reclamation plant was incapable of handling the bacterial load. Since plants can break down and mistakes can be made, there must also be a monitoring system that provides information relatively quickly and not three or five or ten days later when it is only of historical interest. Research at the University of Jerusalem is aimed at developing a rapid test to detect enteroviruses in less than 24 hr.

Shuval felt that if the acid-fast bacteria multiplied in the water environment while pathogens such as salmonella did not, their use as an adequate indicator should be questioned.

Finally, the assertion that acid-fast bacteria are more resistant than enteroviruses was questioned. The level of incoming virus was about 20 per 100 mL, compared to acid-fast bacteria and coliforms at about 10^4 or 10^5 per 100 mL, so that it was difficult to compare kinetics when the initial concentrations were so different. In discussion from the floor, Ramadan (Egypt) stated the topic was interesting and that almost all laboratories are looking for a quick test to identify pollution to the level of bacteria and viruses. However, the acid-fast bacteria lack many of the grounds needed in looking for pollution. First the organism should be present in the human from birth to death. Second, it should not be highly resistant nor should it be pathogenic.

The acid-fast bacteria are not common intestinal bacteria and are highly resistant. This raises the question as to whether they can be efficient indicators or not. A test is needed that is 100% proof of pollution in water.

A. Wachs (Israel) commented that in plants for water renovation, one must look for indicators of treatment efficiency rather than of water pollution. An organism more resistant than pathogens is more useful.

G. Belfort (USA) asked whether or not the efficiency of the concentration methods is crucial both in terms of pathogens and in terms of other materials being concentrated.

Kavanaugh (USA) raised two questions. One was that of simple biological methods for monitoring water reclamation plants. The other was the safety of such plants in producing water of potable quality. The data presented showed about ten samples and that would not seem sufficient evidence for the conclusions drawn in the paper.

In replying to the discussion, Grabow responded to the factor mentioned by Shuval by stating that the acid-fast bacteria test takes four or five days whereas the proper enteric virus tests take four weeks so that the acid-fast bacteria test is still much faster.

With regard to questions on the period where chlorine was not applied in the treatment system, this omission of chlorination was done for research purposes because during chlorination there were no viruses detectable and elimination of viruses in the other treatment stages could not be evaluated.

In terms of the resistance of acid-fast bacteria as compared to viruses, the author averred that it had both in their laboratories and elsewhere as well as in their removal studies here. Their tests have thus far covered more than 11,000 liters without finding any viruses. The research reported is not based on ten or so samples but on research which has been ongoing for many years so that these results reported are based on an extensive, supportive data base.

B. Paper No. 53: "Inactivation of Enteroviruses by Ozone," by D. Roy, R. S. Engelbrecht, P.K.Y. Wong and E.S.K. Chian (USA).

Roy presented this study of a continuous flow evaluation of the kinetics of inactivation of enteroviruses with ozone. Using poliovirus 1 (Mahoney) the research was

directed toward kinetic effects of pH, temperature and ozone concentration. Kinetic experiments were conducted at pH 4.3, 5.9 and 7.2 at a temperature of 20°C and ozone concentration of 0.15 mg/L and at pH 4.3 and 7.2 at 20°C and an ozone concentration of 0.12 mg/L. A verification experiment used echovirus 1 at 20°C, pH 4.3 and 7.2 and ozone concentration of 0.15 mg/L.

The temperature ranges used for inactivation studies were 5°, 10° and 20°C. Ozone residuals were examined at levels of 0.1, 0.12, 0.15 and 0.21 mg/L. Since the experimental apparatus achieved a constant level of influent ozone concentration 15 to 20 min after startup, the first samples for ozone residual determination were collected after 20 minutes of operation. The ozone residual in the reactor did not vary with time after steady state conditions were established. This occurred after five volume turnovers in the reactor. The TOC level of the purified virus suspension containing 10⁶ PFU/mL was measured at 270 µg/L and found to exert a negligible ozone demand.

Radio labeling of the nucleic acid with ³H-uridine enable assay of radioactivity and plaque forming units of different fractions. The sedimentation coefficient of 146S was used to conclude that the viral suspensions used consisted mainly of single virions.

A pH change can affect the inactivation of microorganisms by altering the physiology of the microorganisms or by changing the decomposition rate and/or predominant species of disinfectant. The conclusions drawn from this research were that the rate of inactivation of poliovirus 1 was found to increase with increasing residual ozone concentration in the range of 0.1 to 0.2 mg/L under constant pH and temperature. Secondly, the "all or none" effect associated with ozone disinfection as proposed by some researchers was markedly absent. The resistance of poliovirus 1 increased with decreasing pH and constant ozone residual and temperature. The resistance was attributed to an inherent property of the virus and not aggregation of the virus particles. A similar pattern was noted for echovirus 1. The rate of inactivation of viruses increased with increasing temperature for constant pH and residual ozone concentration. The authors concluded from the calculated activation energy of 3.6 kcal that viral inactivation by ozone is controlled solely by the mass transfer rate of ozone into the virus particle, that is, through the protein coat.

In the formal discussion, E. M. Nupen (South Africa) congratulated the authors on an excellent paper which should be helpful in clarifying much of the existing confusion

regarding the effect of pH and temperature on the efficiency of ozone as a disinfectant, especially as related to virus inactivation.

The authors discussed the possibility that decreased pH values in the medium could lead to virus aggregation and apparent resistance to the disinfectant. Perhaps an added factor is a resistance to oxidation because of protonation. The ozone molecule, O_3 , is an electrophile and will oxidize protonated nitrogenous compounds at a much lower rate than unprotonated compounds which prevail at higher pH levels.

Another factor mentioned which has influenced the observations is a very slight decomposition of ozone to form the much more active hydroxyl radicals. Since this reaction is much more predominant at pH values above eight, it is unfortunate the work was not carried out at still higher pH values.

Nupen looked forward to an extension of the study which would include the effects of higher temperatures, higher pH values and turbidity. She then asked Roy to expand his rationale which led to the conclusion that the rate-limiting step of viral inactivation by ozone appeared to be a mass transfer process.

In the floor discussion, Ramadan (Egypt) expressed interest in the long tailed curve shown in the paper and wondered whether the tailing was due to the presence of another organism in the sample. Shuval (Israel) was also interested in the apparent tailing and thought there could be a sensitive group and a more resistant group. He thought the resistance could be due to changes not detected.

Wachs (Israel) cautioned that laboratory data should not be extrapolated to field conditions.

In answering the discussion, Roy responded to Nupen's query regarding activation energy saying that the value of 3.6 kcal is typical of diffusion processes while chemical reactions have activation energies greater than eight.

He agreed that studies at high pH values would be interesting but noted that a pH in the range of 10 to 12 would kill the virus, it is difficult to get constant ozone residuals at high pH levels, and that high pH levels do not exist in the usual treatment plants.

As to the tailed curve question posed by Ramadan and Shuval, the curve is not due to culture heterogeneity but is

a function of the continuous reactor with $\frac{C}{C_0} = \frac{1}{t}$

The author agreed that any extrapolation of data to regular plant systems would have to be done with great care. Finally, he noted that the water used was ozone demand free, double deionized water.

- C. Paper No. 54: "Study of a Pour Plate Technique for the Enumeration of Coliform Organisms in Surface Water," by J. Vial and Ch. Geoffray (France)

The purpose of this study presented by Vial was to compare a pour plate technique with the classic membrane filter technique and then to discuss the advantages and disadvantages of each method.

In the first part of the study, strains recently isolated from surface water were used to determine whether the two methods could eliminate non-coliform organisms without inhibiting the growth of coliforms.

In the second phase, surface water samples were used to compare results with the routine pour plate and the membrane filter technique. In the final section, river samples were comparatively analyzed by the proposed new pour plate and the routine multiple tube technique. The pour plates used Chapman medium modified from Buttiaux, Muchemle, Leurs, and teepol agar.

The results indicated generally lower recovery with the membrane filter techniques than with the pour plate techniques without inhibitors. The reason proffered was that feeding organisms by nutrient transfer through the membrane was not as adequate as feeding directly inside the medium in the pour plate. The same could be true for the loss of inhibitory activities and the resultant better selectivity on the pour plate as compared to the membrane filter. Their conclusions for these pure strain experiments were that pour plates were more selective than membrane filter techniques and at least as sensitive.

The experiments with river and lake waters from the Rhone Alps region of France showed that truly inhibitory media must be used to provide satisfactory coliform counts especially for total coliform counts at 37°C, otherwise false results can occur in polluted waters giving higher counts on pour plates and lower on the membrane filter. This explains the discrepancies found in the literature between the two methods.

With adequate media, membrane filter and pour plate techniques give similar results. However, the pour plates are faster and cheaper. With judiciously chosen media, the pour plate also provides similar counts to the multiple tube technique but with better precision.

L. Evison (UK) presented the formal discussion. She complimented the authors for their interesting work, made the assumption that the statistics were acceptable and stated that her comments would be confined to the methods and isolation techniques. She commented that it would have been useful to use resuscitation techniques and noted that selection media used to select strains from natural wastes was not mentioned in the paper. Evison requested information on methods used for identification of isolates as to their detail and whether they went beyond the IMVIC tests.

She noted that while pour plates are used they are not popular for several reasons. The pour plates give some degree of heat shock when mixed, they are thought to lead to lower counts, they don't provide a suitable aerobic environment at depth, and there is a difficulty with halos. Probably the convenient maximum is a count of 150 per plate which cuts down on the accuracy reported.

In summary, the pour plate has only limited value, it is difficult to subculture and count, and is restricted to polluted waters. Its use could be improved with newer media. The majority of bacteriologists will probably stay with membrane filter technique.

Ramadan (Egypt), in opening the discussion from the floor, agreed with Evison but wondered why the pour plate method was used to identify coliforms. The fecal coliforms will not be found by the pour plate method. Further, the membrane filter and pour plate are not comparable.

Coin (France) defended Vial's work as undertaken under specific European conditions in an obligatory way. The accuracy was aligned to satisfy specific criteria.

Grabow (South Africa) noted that none of the techniques currently available will detect all the coliforms present in water. Only a small number of the total potential count is measured but even that number counted is sufficient to give a reliable indication of the health aspects and quality of the water concerned. The aim should be to develop techniques that are relatively cheap, rapid, and such that they can be performed by many laboratories; so that there can be standardization among the laboratories. Thus, standardization is the more important point at this time.

Shuval (Israel) noted that to continue Grabow's statement, it is important in monitoring to have a method that will cover the full continuum from the water quality of the river to drinking water. The pour plate technique mentioned cannot cover the full range.

In answering the discussers, Vial first responded to Ramadan that the fecal coliform test does not identify fecal coliform, they are E. coli and similar bacteria that grow at 44°C as defined by the research conditions. In the river examinations, the goal is rather to measure overall pollution.

Resuscitation tests are not used in France but it would be desirable to use this method. Sodium laurel sulfate is used in England to replace teepol which is not available in England, but teepol is available in France. The isolates were all river strains which were previously isolated at 20°C by oxidase, IMVIC and the Mackenzie tests.

As to the thermal shock of the pour plate, the fecal coliform are heat resistant so the heat only helps select the desired organisms. Further, the anaerobiosis which might be in the dish is not bothersome to the cultures of interest.

As to counting, it of course, takes longer to count more colonies but it is no more difficult than other methods. This is a method for surface waters where there is not a need for specific identification. With the halo colonies, it is, of course, not possible to count 300 colonies, but with clear agar, it is easy to make counts up to about 150 colonies.

- D. Paper No. 55: "Efficiency of Ultrafiltration for the Isolation of Enteric Viruses and Coliphages from Large Volumes of Water in Studies on Wastewater Reclamation," by E. M. Nupen, N. C. Basson, and W. O. K. Grabow (South Africa)

E. Nupen presented the study on the efficiency of a pressure ultrafiltration procedure using flat membranes for the recovery of viruses from water from different purification stages of the Stander Wastewater reclamation plant, Pretoria tap water, and sterile glass distilled water. The raw water intake of the Stander plant was activated sludge effluent and the sequence of unit processes in the plant were primary ferric chloride clarification, secondary ferric chloride clarification with or without chlorination, sand filtration, ozonation, activated carbon adsorption and final chlorination.

Numbers of coliphages were high enough for direct assays on unconcentrated samples of the raw water intake, water after primary clarification and even after secondary clarification and sand filtration when prechlorination was omitted. Thus, direct assay of coliphages was possible on original samples and 20 mL concentrates. Counts of enteric viruses and SA 11 virus were too low for direct assays even in the raw water intake so recoveries of these viruses were evaluated by seeding into virus free samples of the final reclaimed water, tap water and distilled water and comparing counts in the seeded samples with those in their concentrates. Similar experiments were done with water samples seeded with selected morphological types of coliphages. Chlorine was neutralized with sodium thiosulfate.

The efficiency of coliphage recovery by the pressure ultrafiltration procedure correlated inversely with the amount of suspended matter in the samples tested, probably because of the adsorption of phages on suspended particles which tend to centrifuge out during the decontamination stage. Recovery of enteric and other viruses is probably similar.

The recoveries of viruses from distilled, tap or reclaimed water did not differ significantly since they did not contain high enough quantities of suspended matter to affect recovery efficiency of the ultrafiltration procedure even when 50 L were passed through individual membranes. Thus, the ultrafiltration process is equally efficient for a wide variety of viruses.

Ultrafiltration has various advantages over other virus concentration techniques. The average efficiency of 94% for recovery of a wide variety of viruses from tap or equivalent water is higher than the 35 to 70% recovery for adsorption-elution techniques currently recommended for recovery of picornaviruses from similar water. In addition, ultrafiltration is relatively simple and economical, standard equipment is available, no chemicals have to be added to the water samples, viruses are not exposed to pH extremes, no secondary concentration step is required, and sterilization of equipment is simple and reliable. The disadvantage of flat membrane ultrafiltration is the slow flow filtration rate, but considering the disadvantages of the other systems, the 40- to 72-hr filtration time for 50-L samples of tap or similar water is not a serious factor. This time factor did not seem to alter virus survival.

The ultrafiltration method suggested in this paper limits the virus contamination to an absolute minimum.

In his formal discussion of the paper, Vilagines (France) referred to the 40- to 72-hr filter time for 50 L as slow compared to processes he uses to filter 500 L in less time. The filtration speed doesn't affect the overall process but the laboratory gets cluttered with samples. The yields obtained in this research corresponded to values in the literature.

L. Coin (France) also commented that the work was of high quality as were the phage photos. He had tried the techniques and could not duplicate the recovery presented by the authors. With the numerous problems encountered he abandoned the method.

Belfort (USA) opened the floor discussion by expressing concern that all ultrafiltration processes are considered on the basis of the use of one design. He asked why the flat membrane was used when faster column systems were available with rates as high as 50 L in 43 min. He also cautioned about extrapolating data from two L samples to 100 L.

Shuval (Israel) noted the high efficiency recovery reported here. There is need to attain assays that can report water quality before the water is delivered. There are some fluorescent techniques that may be able to identify virus within 24 hr and the factor then becomes a real time condition.

In his response to the discussion, Nupen stated that the work in South Africa has been ongoing for many years and it was assumed that their methods were well known. They have looked at fluorescent body techniques; they are interested in more rapid filtering techniques and have reviewed other possibilities such as hollow filters but so far they are very expensive and not as efficient in recovery, and the volume is 100 mL.

No difference was found in recovery at two L and 100 L. Further, the comments regarding coliphage size were in error. Two were used, one near the size of the poliovirus.

IV. CRITIQUE OF SESSION

The discussions following the papers were interesting in expressing again the views of the microbiologist in seeking better laboratory evaluation of organisms and the engineer in seeking eventually almost immediate indications of water safety. Many of the discussion points revolved around this difference in perspective, with engineers using organisms as indices of

possible pathogenic contamination and virologists or bacteriologists discussing identification of specific microbial entities. The papers and comments then need to be reviewed from the perspective of intended use of the collected data. The other bifurcation occurred between those interested in laboratory research and those who interpreted data from full-scale field operations.

The papers and discussions are in large part continuation reports of the participants' ongoing research in microbiological aspects of water quality control. The floor discussions then become a part of the annals of this international group and the critique here is only that at a window in time. With this type of research, equipment, expertise and experience are essential in establishing the base lines of data for providing reliable, safe water and prompt indication of potentially harmful infections. Thus, experimental work can be expected to extend over long periods of time with periodic updating and discussion a necessary checkpoint for retaining the flow of information beyond the formal written word. These international sessions are valuable opportunities providing the profession access to these ongoing chronicles of research.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

In the wastewater reclamation area, the research presented here is important for those areas of the country where water is potentially in short supply. The studies on indicator organisms and on mechanisms for assurance of reliable, safe, reclaimed water supplies are areas of concern. Indicator assays especially need to be further developed to provide reliable, rapid assurance of valid quality control at reasonable cost and within the capability of most laboratories.

The multiple barrier systems discussed in some of these papers together with the concept of reliability of operation, both equipment and human, need to be developed to assurance levels that allow more rapid enhancement of water reuse especially in terms of concurrent energy conservation.

I. SESSION

A. Day: Tuesday, June 24, 1980
Hall: C
Time: 2:00 pm to 4:15 pm

B. Theme of Session: Eutrophication

II. REVIEWER

A. Name: Joseph F. Malina, Jr.

B. Position and Affiliation: Professor and Chairman
Civil Engineering Depart.
University of Texas
Austin, TX

III. DESCRIPTION OF SESSION PAPERS

A. Paper No. 56: "The Chemical Control of the Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms)," P. J. Ashton, W. E. Scott and D. J. Steyn (South Africa)

An infestation of *Eichhornia crassipes* (Mart.) Solms on the Hartbeespoort Dam reservoir (approximately 12 km²) was successfully treated with a terbutryn herbicide (Clarasan 500FW). Foliar symptoms were typical of plants treated with triazine derivatives and herbicidal action was slow. Death, decomposition and subsequent sinking of the treated hyacinth plants took four to five weeks, causing a gradual depletion of oxygen in the water. Potassium, sodium, nitrogen and phosphorus levels in the impoundment increased, particularly in the surface water. Unsprayed plants had high growth rates, necessitating effective follow-up action. Water samples had consistently low levels of herbicide residues, while samples of fish viscera showed some temporary accumulation.

This paper was presented by Ashton. Impoundments and rivers in South Africa and the Southern Hemisphere are plagued with water hyacinth infestation. Biological and mechanical control measures have not been effective. In deciding to use the herbicide, terbutryn, the effects on the water hyacinth, the production of potable water supply and the effects on other aquatic biota were considered. Four aerial applications were made at a dosage rate of three L of active ingredients per hectare of weed. The slow action of terbutryn resulted in progressive killing of the weed and

although anaerobic conditions developed in the hypolimnion, the dissolved oxygen levels in the epilimnion were between 75 and 80% saturation. Plants in remote places were sprayed by hand application. No mature plants were detected in the reservoir nine months after the application of the herbicide. However, the released nutrients caused massive blooms of blue-green algae.

The invited discussor of the paper was H. Hughes (New Zealand). Terbutryn also was under evaluation in New Zealand for aquatic weed control. The rates of application are a function of the climate, species of plant and the hardness, pH, and alkalinity of the water. The time interval between the first and second spraying is critical with slow acting herbicides, since unsprayed plants grew more prolifically because of the nutrients released by dying plants. Replacing water hyacinth infestation with the blue-green algae blooms was not really a solution since the algae affect the water supply and the recreational use of the water. An overall nutrient control program for the entire catchment area was necessary.

In replying to Hughes, Ashton stated that the cost of the water hyacinth control program was \$600,000 US dollars; however, more than \$15,000,000 US dollars are spent annually since the reservoir is heavily used for recreation by residents of Pretoria and Johannesburg, South Africa. Blue-green algae were acceptable to boaters, but the water hyacinths were a nuisance and inhibited boating. Effluent quality standards for sewage treatment plants in the catchment area were established to control the nitrogen and phosphorus inputs; however, runoff carries nutrients into the reservoir.

The herbicide 2,4-D has been effective in controlling aquatic weeds, *Myriophyllum* in Canadian lakes (Isenhauer), water hyacinths in Zimbabwe, (McKendrix) and hydrilla and water hyacinths in Fuji (Hugh). In Zimbabwe health authorities limited the applied concentration to one-one hundredth of a safe dose although they would have preferred to use one one-hundredth of the applied dose. In South Africa, 2,4-D was not approved for use. The rapid action of 2,4-D on water hyacinth would have turned the entire Hartbeespoort Reservoir anaerobic.

In discussion from the floor, Smalls (Australia) stated that macrophytes near the shore use nutrients which would be available to algae resulting in better water quality and easier water treatment. However, the area of hyacinths required for nutrient removal would be two and a half times the area of the Hartbeespoort Reservoir. In addition, growth of hyacinths interfere with anglers and the hyacinths do not

survive cold temperatures and would release nutrients during the winters.

Shelef (Israel) mentioned that harvesting hyacinths for animal feed for production of biogas has been considered and rejected because of the high transport cost (hyacinths contain 95% water). Removal of water from the plants on site presents the problem of treatment for nutrient removal.

Herbicides can be used for controlling water plants but must be used with extreme caution in water supply reservoirs. Public resentment to the use of herbicides in water supplies was high initially; however, after laying out the facts to the public, developing and sustaining public support, the use of herbicides for the control of water hyacinths has been effective. In this particular instance, the public pressures forced diverse interest groups to cooperate in controlling the water hyacinth problem.

- B. Paper No. 57: "The Stimulation of Autotrophic Production by Urban Stormwater-Borne Nutrients," T. J. Grizzard, R. N. Waterman, C. W. Randall and R. C. Hoehn (USA)

Composite samples of stormwater runoff were collected from thirteen urban catchments representing six homogeneous land uses in the Virginia suburbs of Washington, D. C. Phosphorus and nitrogen concentrations and availability in the stormwater samples were found to be sufficient to support moderate to high levels of production of the test alga, S. Capricornutum. Lead and zinc concentrations in stormwater from certain urban land uses were found to be inhibitory to algal production. The annual average biomass to be supported by urban stormwater was found to bear a generally positive relationship to density of development. Nutrients in urban stormwater caused algal growth in reservoirs after periods of runoff. Nitrogen was limiting in the algal growth assay for samples from residential areas while phosphorus was limiting in commercial runoff. There was good correlation for the inhibition of zinc; however, lead indicated a negative correlation. The invited discussor for this paper was absent from the meeting.

Malina (USA) stated that oil and grease in the runoff may have had an inhibitory effect in the algal assay test. Hugh (New Zealand) commented that dogs and cats in the catchment area also contribute nutrients to the runoff. On a unit area basis particulate nutrients in runoff from urban areas was one and a half times higher than for agricultural areas. Approximately 20 to 25% of the nutrients discharged

from urban areas are soluble. Phosphorus is cycled from the particulate to soluble fractions. However, only the soluble fraction (filtered samples) were used in the assay test. Selective extraction procedures minimize inhibition during the algal assay test encountered with filtered samples (Lijklema, Netherlands).

The objective of the study was to develop gross data to evaluate the effects of runoff on one algal species and to establish the cost and impact on the receiving stream.

C. Paper No. 58: "The Sensitivity to Phosphorus and Nitrogen Loads, of Lake Rotorua, New Zealand," R. A. Hoare (New Zealand)

The loads and outflow of phosphorus and nitrogen in 1976 and 1977 are reported. Four expressions from the literature are used to estimate expected retention coefficients for phosphorus, and are compared with measured values, the ranges being 0.50-0.66 for the literature-based estimates and 0.47-0.68 for the measurements, the values for the latter being dependent on how much of the particulate nutrient load is included. Much of the nitrogen load appears to be lost to the atmosphere. Estimates are made of the effect that changes in sewage load will have on the annual mean phosphorus and chlorophyll concentration in the lake.

The catchment area of Lake Rotorua is primarily pasture land with some beaches. The town of Rotorua is located directly on the lakeshore. In 1975, massive algal blooms reduced Secchi disc readings from 2.5 m to 1.5 m. Based on the nutrient budgets, about 70% of all the phosphorus entering the lake remains in the sediments and about 66% of the nitrogen either stays in the sediment or is lost in the atmosphere by denitrification. If the amount of phosphorus in the sewage discharged into the lake were reduced to zero as a result of diverting all sewage from the lake at a cost of \$5,000,000 US dollars, or if the phosphorus from the sewage doubled, the total change in phosphorus in the lake which is 30 mg/m³ is predicted to change by 6 mg/m³ or a change of about 20%.

Ashton (South Africa) was the invited discussor. Lake Rotorua is a typical eutrophic lake. The contribution of nutrients from sewage accounted for only 13 to 15% of the total nutrient inflow to the lake. The macrophytes recycle nutrients and phosphorus associated with the sediments is released under anaerobic conditions.

Phosphorus is taken up by the algae, primarily diatoms, and approximately one meter of diatoms have

accumulated since the lake was formed by volcanic activity in 1886. No data on the release of phosphorus from the macrophytes or the algae was available.

Nitrogen and phosphorus loading expressed in terms of annual averages is not very meaningful since seasonal peaks lead to undesirable blue-green algae blooms and bad public reactions.

Geothermal activity around the lake (Shelef, Israel) releases large concentrations of ammonia; however, these discharges have a flow of approximately one L/s (16% of the total inflow) and ammonia concentrations of 600 mg/L. Rainfall is the second largest contributor of nitrogen to the lake. Removal of phosphorus in the sewage by discharging the effluent to the Sulfur Bay containing large clay deposits was not feasible since these clays are already saturated with phosphorus. However, there is no noticeable release of phosphorus from the clays in this area.

The discussion focused on the cause of blue-green algal blooms. The species of blue-green algae which form the scums may be nitrogen fixing organisms and should give an indication of which element is limiting (Scott, South Africa). Blue-green algae are potentially nitrogen fixers, but just how much effect this has on the lake is questionable (Hoare).

In 1974 there were prolonged dry periods in the Southern Hemisphere and this dry period was followed by large floods which flushed large quantities of phosphorus into the lakes (Howard, Australia). The blue-green algae, anabaena and anacystis prevailed in many of the lakes. These algae are known to fix nitrogen when phosphorus is present in the water. However, at a nitrogen to phosphorus ratio of 30:1, anabaena was present. Basalt outcroppings in Lake Rotorua may add the trace nutrients which are required to trigger blue-green algae. Other lakes without this soil formation did not experience algal blooms.

The appearance of anabaena also were observed after long periods of lake stratification. Blue-green algae grow at low light levels and contain gas vacuoles which permit them to sink or float to the depth for maximum growth. Blooms of blue-green algae also occur at times of silica deficiency usually following blooms of diatoms (Aulenbach, USA).

IV. CRITIQUE OF SESSION

The papers dealing with the control of water hyacinths and the eutrophication of Lake Rotorua were well received and extensively discussed. The development and

application of various herbicides for the control of aquatic weeds, hyacinths, hydrilla and others which plague many of the southern recreational and water supply lakes is of importance to USA water quality engineering and management efforts. Diquot, another herbicide, could be used for spot treatment of the nuisance weeds. This compound is effective in soft waters, they react with clays and are readily broken down in water. Terbutryn also could be used to control aquatic weeds in the USA. the release of nutrients from the decaying macrophytes results in extensive algal growth. In some of the USA lake it could be better to develop more effective macrophyte mechanical harvesting equipment rather than recycle nutrients.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The control of nitrogen and phosphorus in runoff and other non-point sources is essential to the upgrading and maintaining of water quality in lakes and rivers. In many catchment areas, treated sewage contributes far less nutrients than runoff. There apparently is a lack of consensus on the cause and effective control of blue-green algal blooms in lakes and reservoirs. In addition to nitrogen and phosphorus, the trace elements which trigger algal blooms should be clearly identified.

Research on the effect of various herbicides on aquatic weeds could be directed at solving some of the problems plaguing some reservoirs and lakes in the USA. However, the release of nutrients, and subsequent algal growth, changes in water quality, depletion of dissolved oxygen, and the effect on water treatment must be considered.

I. SESSION

- A. Day: Wednesday, June 25, 1980
Hall: A
Time: 9:00 am to 12:30 pm
- B. Theme of Session: Contamination of Surface and Subsurface Systems from Waste and/or Waste Residue Disposal on Land

II. REVIEWER

- A. Name: Riaz Ahmed
- B. Position and Affiliation: Senior Research Scientist
The Center for the
Environment & Man, Inc.
Hartford, CT

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 59: "Lysimeter and Field Studies on Land Application of Wastewater Sludges" by M. D. Webber, Y. K. Soon and T. E. Bates (Canada)

Lysimeter studies at Burlington, Ontario and field studies at Guelph, Ontario, were undertaken in 1973 and 1974 to determine the effects on crop yield and quality and on groundwater quality of land application of sludges containing Al, Fe and Ca added to remove phosphorus from wastewater. Similar results were obtained from the lysimeter and field experiments. Orchard grass, brome grass, wheat and corn yields with sewage sludge were as large as, or larger than, with commercial fertilizer and there were no consistent differences between yields from the Al, Fe and Ca sludge treatments. There was no evidence of yield reduction even from the highest rates of sludge application which ranged up to 499 tonnes·ha⁻¹ of dry solids. The crops exhibited similar metal contents and similar responses to large amounts of metals in the sludges. Both experimental situations indicated a potential for groundwater contamination with nitrate-N when a sludge application was in excess of that necessary to supply the nitrogen requirement of the growing crop. The results indicated that sludge application to land, according to the OMAF/OMOE Guidelines, would not reduce the yield or quality of the four test crops nor would it reduce groundwater quality.

Webber made the presentation. It was noted that in 1969, the International Joint Commission recommended removal of phosphorus from point sources. In Ontario treatment plants, phosphorus is being removed through addition of alum, waste pickle liquor, or lime. The objective of the study was to assess the fertilizer value of the sludge generated from those three processes. The criteria used in determining the value were crop yield, crop quality, and groundwater quality.

Orchard grass and wheat were used as test crops in lysimeter studies. Field experiments used brome grass and maize as test crops. Field experiments covered a total area of 0.5 ha and included several replicates. Sludge loadings were based upon total Kjeldahl nitrogen and varied from 200 to 1600 kg/ha/year. Control experiments received NH_4NO_3 and application rates varied from 100 to 400 kg $\text{NH}_4\text{NO}_3\text{-N/ha}$. At high values, the rates of application are three to five times more than the recommended guidelines of the Ontario Ministry of Agriculture and Food, and the Ontario Ministry of Environment (OMAF/OMOE).

The authors were satisfied with crop yield, crop quality and groundwater quality. No differences were observed between lysimeter and field experiments. Crop yields under sludge treatments were the same as those obtained with the application of commercial fertilizers. As a matter of fact, at a high rate of application, the yields were higher from sludge treatments.

Crop quality was concluded to be not affected by sludge treatment except in cases where treatment rates were much higher than the recommended values. As a general rule, phosphorus content of plant material did not increase in spite of the fact that sludge contained tons of phosphorus. Nitrogen content in plant matter was observed to be generally below two mg N/g of plant material. At 3 mg N/g plant material would be toxic to cattle. Metal content increased very slightly but was well within the range of normal variations. As expected, the biggest increase in metal concentration occurred in corn stover. An observation was made that sludges with high metal content resulted in higher metal content of the plant material.

Groundwater quality was observed to be good except where sludge application resulted in nitrogen inputs much greater than the needs of the crops. From the water quality point of view, 11 mg/L $\text{NO}_3\text{-N}$ is considered limiting. Leachate from lysimeters often had concentrations as high as 100 mg/L. All metals were observed to be below the drinking water standard.

In summary, Webber concluded that sludge applications at a rate recommended by OMAF/OMOE and at higher rates did not impact crop yield, crop quality and groundwater quality. He noted that further work includes use of vegetable crops.

Hall (South Africa) presented the formal discussion. He noted that sludge is a resource; however, it also has many constituents whose deleterious effects may or may not be fully known. A study by Marx and Kay in Johannesburg in which digested sludge was dried and worked into the soil showed that the heavy metals were retained in the upper 25 mm of the soil. Zinc content of soil had increased from 931 mg/kg of soil to 3073 mg/kg. It was not, however, observed in subsurface water. On the basis that the metal will stay in the upper layers, he raised the question of a practical total application limit. Also, the impact on animals consuming such crops is of concern. In South Africa, liver examinations of cattle showed zinc content of 500 mg/kg. This high concentration is attributed to sludge. He mentioned the hazards associated with transmission of viruses, pathogens and parasites. In South Africa, parasites have been a problem. These potential health hazards assume a more significant role if sludge was applied to vegetables or other leafy crops.

In light of practical application limits, another potential problem is the lack of past history of a potential application site. Very often, commercial fertilizers have heavy metals in significant quantities.

In replying to Hall, Webber indicated that mass balance analysis was attempted, however, he provided specific conclusions only for nitrogen. A substantial portion of nitrogen was not accounted for, thus indicating existence of denitrification. Phosphorus build-up in soil was as high as seven to eight metric tons per hectare. Since sludges were not worked into the soil, 99% of the metals were observed in the sludge layer and top one cm of soil. No metals were observed below 5 cm. Regarding viruses, pathogens and parasites, runoff plots were established at the University of Guelph and runoff was monitored for metals and microorganisms. Results were essentially negative and after four years, the experiment was abandoned. No more than one percent of the samples showed salmonella and similar conclusions can be drawn for viruses. From the point of view of instituting land disposal of sludge, it would require an approval from the Ontario Ministry of Environment and sites having high background metal levels will not be approved.

Young (UK) opened the floor discussion by reporting

work in the UK where 1000 kg/ha of sludge was applied to grasslands over limestone aquifers. Sludge was from a treatment plant which also served industries. No heavy metals were detected in soils except zinc, which was still less than the background concentrations in the aquifer. Nitrogen was existent and was expected to reach the aquifer eventually.

Hallquist (Sweden) brought up the subject of the effect of pH on uptake of metals. Mijares (Venezuela) noted that studies in Venezuela show sludge dried to less than 60% water kills parasites. McKendrik (Zimbabwe) posed the problem of flies and odor.

Webber noted that pH of soil either remained constant or increased. Even iron sludges were neutral as lime was added to stabilize the sludge. No odor or fly problem was experienced at the site. Microorganisms were not a problem.

- B. Paper No. 60: "Operation and Design of Biological Leachate Treatment Plants," by R. Stegmann and H. J. Ehrig (West Germany)

The biological treatment of leachate from municipal sanitary landfills is a successful method of purification. The basic data presented includes leachate quality (BOD_5) and leachate production relative to the "age" of the landfill and with respect to the degree of compaction and climatic conditions.

Aerobic lagoons were run with leachates from different sanitary landfills as pilot plants in a laboratory experiment. The data obtained is evaluated with regard to final BOD_5 effluent values dependent on the organic load- B_R ($kg\ BOD_5/m^3 \cdot d$). Similar evaluations were made with data obtained from a full-scale aerated lagoon system that treats the leachate of the sanitary landfill in Lingen, West Germany. As could be expected, in comparison with the pilot plants, larger detention times are required in the full-scale plant.

Although some experimental aerobic biological treatment plants are available, the operation and supervision of full-scale plants, where aerated lagoons as well as activated sludge processes should be used, is desperately needed.

Stegmann, in presenting the paper, noted that studies in Germany show that biological treatment processes

(aerated lagoons and activated sludge) can be used for leachate treatment. Proper aeration of these processes requires availability of sufficient quantities of nutrients provided that loading rates and detention times are adequate. However, the effluent is still expected to have COD concentrations of 300 to 1500 mg/L. COD, if necessary, may be removed by physical/chemical processes.

In order to design a treatment plant, one must have a knowledge of BOD₅ concentration of leachate relative to the age of landfill and leachate production rates. Based upon a survey of 15 landfills in West Germany, they concluded that leachate production is a function of annual rainfall and the degree of compaction. Initial leachate BOD concentrations are 1500 mg/L and 7500 mg/L for high compacted and low compacted landfills, respectively. With time, BOD concentrations decrease and, in both cases, eventually level off to 250 mg/L. Ammonia concentrations were as high as 1300 mg/L.

Since 1971, several laboratory and pilot plant studies have been conducted for biological treatment of leachate. Four years ago, a full-scale aerated lagoon plant with spray irrigation of effluent was built at Lingen, Germany. Also, an activated sludge treatment plant has been in operation for the last couple of months at Kassel. More plants are under construction. The authors noted that the experiences of laboratory studies and full-scale plants are quite different and, hence, design criteria must be established on the basis of a thorough monitoring of an actual plant.

In addition to BOD, BOD to COD ratio also reduces with age. Experiences at Lingen indicate that the loading rates are a function of this ratio. However, if the ratio is greater than 0.05 and less than 0.4, the detention time is independent of this ratio.

Due to long detention time, temperature effects were of concern. It was noted that the lagoon with diffused aerators did freeze at temperatures of -20°C. Even at this low temperature, treatment was satisfactory. Addition of excessive amounts of phosphorus led to production of excessive amounts of algae unless the lagoons were artificially aerated. Foaming was another problem experienced in the operation of the lagoons. Spraying the foam with leachate solved this problem. Spray irrigation did not cause any odor problems.

Experience with the activated sludge plant indicates the sludge settleability is good. Return sludge

concentrations ranged from 12-15 g/L. For influent BOD concentration of 880 mg/L, the effluent concentration was 16 mg/L. In general, the authors considered activated sludge plants to be very promising for leachate treatment.

Pohland (USA) presented the formal discussion. He recognized the authors' exhaustive review of the studies in West Germany and emphasized the timeliness of the subject. He noted that leachate generation is a dynamic process. While agreeing with the authors on the factors affecting leachate production, the simple relationships as proposed by the authors are not realistic due to possible short-circuiting of leachate through the landfills, rainfall variability, and local pockets of biological activity. Variability in rainfall may cause little or no leachate generation in certain months of the year and, hence, the use of mean values of leachate generation in these areas is not appropriate. He noted that in homogenous landfills, BOD concentration may initially rise and then subside while, in heterogenous landfills, concentrations may rise and then subside only to rise again in an indeterminate fashion due to pockets of localized activity. The duration of each sequence of leachate generation will depend upon substrate quality and other environmental factors.

Relating to the emphasis on nutrients, he noted that nutrient levels will affect the BOD to be treated either in situ or in an external set-up. He also noted that landfills could themselves attenuate BOD, provided nitrogen and phosphorus are available. In an external treatment environment, the lack of phosphorus probably is of more concern than the abundance of nitrogen. He disagreed with the authors on the role of NH_3 -nitrogen. Pohland noted that in such an extended aeration system, the oxygen requirement of NH_3 -nitrogen could not be detrimental.

Pohland went on to say that while aerobic processes may be feasible under controlled loading conditions, their feasibility for actual field conditions is questionable. Both processes are vulnerable to leachate variability. Aerated lagoons enjoy resistance to volumetric shocks but are sensitive to biological mass variability. On the other hand, activated sludge plants may be vulnerable to volumetric shocks. Further, the nature of biological compounds vary with leachate age. Young leachates have large quantities of readily biodegradable organics while older leachates have mostly refractory organics. Thus, with age, BOD and BOD to COD ratios change and hence the percentage removal required to reach a desired effluent concentration will also change. Consequently, a leachate treatment program must be flexible enough to accept the variability in leachate and still provide treatment in a cost-effective way.

As a conclusion, he questioned the feasibility, reliability and cost-effective operation of a leachate treatment system optimized on the assumption of a quasisteady state loading rate. The variability in leachate production rate and its characteristics weakens the case for a separate treatment. He noted that previous studies have shown that both aerobic and anaerobic processes can treat leachate at the same cost under controlled loading conditions. Naturally, variability in leachate, however, demands a more resilient process, such as leachate recycling and land treatment. Experiences in the USA and Canada show that such processes cost less and provide opportunity for increased energy recovery. He posed the question of extension of this type of work in West Germany.

The authors in general agreed with the comments of the discussor. In reply, they noted that the use of average leachate generation data is similar to the use of design values for domestic wastewater treatment. In terms of system stability, they noted: (1) low loading rates and long detention times of the reactor; (2) in activated sludge units, the settling tanks are designed for maximum volumetric loadings; (3) in the case of excessive variability, one can use equalization basins after the activated sludge units; (4) in case of very concentrated leachate, it may be recycled onto landfill.

In the discussion from the floor, Ahmed (USA) inquired about the variability of leachate BOD concentration, heavy metals and their toxicity to biological systems and methods of disposing sludge from treatment processes.

The authors replied that since all landfills monitored experienced the same climatic conditions, contained only domestic waste and were sealed at the bottom, the leachate variability was no more than $\pm 50\%$. They further noted that the high variability reported in literature may be due to the fact that landfill leachates have been diluted by subsurface water. The dilution can be ascertained if the BOD to COD ratio is less than 0.5. Again, the domestic nature of the waste resulted in minimal metal concentrations. Sludge is collected and placed on top of the landfill.

Young (UK) reported on a pilot 2-m³ landfill study in which rapid BOD reduction was obtained by amending the leachate through phosphorus addition. The authors noted that they have tried the approach but the results were negative.

McKeown (USA) and Yank (Canada) inquired about the biodegradability of refractory compounds (COD) in the effluent. Yank asked about sludge age and questioned the

feasibility of aerated lagoons as an option in cold climates.

In reply to McKeown and Yank, the authors quoted the work of Chian and DeWalle (USA) stating that the refractory compounds are folic acid types and difficult to degrade. They noted this is a future subject for research including physical and chemical treatment to remove these substances from effluents. Also, under discussion is the effluent criterion for COD. In reply to Yank, the authors noted that even at -20°C , the effluent BOD concentration for aerated lagoons was 40 mg/L. Perhaps the activated sludge plant is more suited due to its shorter detention time.

As a concluding remark, the authors made the point that anaerobic processes may not be effective if leachate BOD concentrations are below 250 mg/L. Stegmann later made the point that for existing landfills the general practice is to install groundwater monitoring wells. Cases of groundwater contamination due to landfills exist. However, all future landfills are to be sealed. Further, municipal and industrial wastes are placed in separate locations. Young (UK) told Ahmed (USA) that their experience in the UK indicates wide variability in leachate concentration and production rates.

- C. Paper No. 61: "Treatment Effects and Pollution Dangers of Secondary Effluent Percolation to Groundwater," by E. Idelovitch and M. Michail (Israel)

Percolation of secondary effluent from oxidation ponds to the groundwater aquifer, which was studied in a large-scale field operation, acted as an efficient advanced wastewater treatment system. Excellent removal was obtained by effluent passage through the soil-aquifer system for several important pollutants, including: phosphorus, particulate organic matter, coliform bacteria, cadmium and chromium. Good removal was also obtained for soluble organics (expressed as DOC or filtered KMnO_4 consumption). Complete nitrification and good denitrification were obtained during a period of several years, but then an increase occurred in the nitrogen concentration — in the forms of ammonia and organic nitrogen — which presumably indicates that anaerobic conditions which might become prevailing in the aquifer can impede the completion of the nitrification process. The main dangers of groundwater pollution by seepage of effluents from oxidation ponds appear to be connected with soluble organics and unoxidized nitrogen forms.

Idelovitch presented the results of the studies connected with oxidation ponds in the Dan Region

Wastewater Reclamation Project. Oxidation ponds which have many advantages do pose the problem of groundwater contamination. The ponds in the Dan Region have been in operation since 1970 and were constructed on sand without a clay layer thereby permitting significant quantities of effluent to seep to a perched aquifer. Later on, the water from this perched aquifer spilled over to the main aquifer. However, within two to three years, the seepage rate from the pond reduced to a few mm per day. Initial seepage has resulted in contamination of production wells. The nearest production well, 250 m from the pond, has been abandoned.

The study reported the movement of pollutants in the aquifer. Several observation wells were monitored. Chloride was used as a tracer principally due to the fact that it is not attenuated by soils and there was an order of magnitude difference between chloride concentration in the effluent and the groundwater. Simple mixing equations were used to compute percentage of effluent in a well. For other parameters, the removal efficiency of soil was computed using the observed concentration values and concentrated values expected on the basis of the percentage of effluent in well water. Percolation resulted in advanced wastewater treatment through mechanisms such as slow sand filtration, biological degradation, nitrification and denitrification, chemical precipitation, adsorption and ion exchange. Parameters monitored were nutrients (N,P), particulate and dissolved organics, coliforms, heavy metals, cadmium and chromium. Phosphorus, coliforms and particulate organics were totally removed. Dissolved organics were removed by 60 to 70%. Chromium and cadmium concentration increased very little from background concentration.

It was noted that as far as nitrogen is concerned, there are three distinct periods of behavior. The nitrogen in pond effluent is of organic form and as the effluent reaches the aquifer, the nitrogen in the effluent is transformed to nitrate. As more of the effluent reaches the aquifer, denitrification starts taking place in the aquifer. This period results in a minimal increase in Kjeldahl nitrogen concentration in the aquifer. During this period, nitrogen concentration in groundwater is minimal; however, this is a temporary phase. As more effluent reaches the aquifer, total nitrogen concentration increases in parallel with the increase in Kjeldahl nitrogen. A large amount of data on wells substantiates this three-period behavior of nitrogen.

As a conclusion, Idelovitch noted that percolation results in advanced levels of treatment of effluent and the long-term groundwater problem is contamination due to unoxidized forms of nitrogen.

McKendrick (Zimbabwe) opened the formal discussion by congratulating the authors for the excellent work and emphasized the need to do a thorough study of the effects of human activity on groundwater. He pointed out that the experience in Zimbabwe shows coliform contamination of the aquifer. He also noted that sudden increase in chloride concentration in a well is indicative of a plug flow type movement. Specifically, he posed the following questions: (1) what is the source of high Na concentration in secondary effluent?; (2) what are the possibilities of phosphorus release as the conditions in the aquifer become anaerobic?; (3) since 1977, the effluent has gone through tertiary treatment. Has this resulted in improvement in well water quality? (4) if no improvement has been observed, does it mean that the aquifer will have to be abandoned as a source of water supply?; (5) what is the quality of tertiary effluent?

In replying to McKendrick, Idelovitch noted that seepage from the ponds was a temporary situation. The ponds are naturally sealed now; however, the seeped effluent has reached the aquifer. Since the aquifer contains fine sand, it has acted as a slow sand filter resulting in the removal of coliforms. The high source of Na is the lake water used for domestic purposes plus domestic additions of Na. While laboratory studies indicated eventual release of phosphorus, it has not been observed in the field. As far as questions relating to tertiary effluent, he referred to his paper being published in the July issue of the Journal of the American Water Works Association.

In order to handle the present contaminated conditions of the aquifer, he offered several possibilities; post treatment of aquifer water by activated carbon, use of well water for agricultural purposes, and others. Currently, the water from contaminated wells is being used for carbonation purposes in the tertiary treatment plant. It is added to the effluent process stream after lime treatment. This also tends to dilute the effluent.

In the floor discussion, Morioka (Japan) inquired about possible soil clogging due to anaerobic conditions and its impact on well water quality. Parker (Australia) asked about the concern of the dissolution of manganese from soil as it was raised in the initial planning studies. Ramadan (Egypt) asked if in the use of this water, chlorine was added. Ahmed (USA) inquired if DO was monitored in the wells and did anaerobic conditions result in changes in the hydraulic characteristics of the aquifer. Reeves (Netherlands) wanted to know about the grain size distribution in view of the excellent removal of coliforms.

Idelovitch, the author, noted that coliforms were not observed even in the nearest wells. Soil clogging was not a problem because large amounts of water supplied from the surrounding region provided a balance between aerobic-anaerobic conditions in the aquifer. This is in spite of the fact that anaerobic conditions existed below the ground.

- D. Paper No. 62: "Nitrogen Removal in a Subsurface System," by A. Andreoli, R. Reynolds, N. Bartilucci and R. Forgione (USA)

Contamination of groundwater by nitrates from individual septic tank leaching systems is a potentially serious public health problem in Suffolk County, where groundwater is the sole water supply source for its 1,300,000 inhabitants. This study investigated the possibility of developing a system for eliminating nitrate-nitrogen from wastewaters which would otherwise leach through the soil and contaminate the groundwater.

A conventional septic tank-leaching field residential subsurface wastewater disposal system was constructed. A pan-shaped impermeable membrane was installed in the soil below the leaching field to collect and detain the leachate. Methanol, as a carbon source for denitrification, was injected into the pan.

After more than one year of operation, it was found that the system is capable of reducing nitrate-nitrogen to well below the recommended public health limit. Findings indicate that the system exhibits potential for development of a practical method of nitrate removal in subsurface wastewater disposal systems.

In Suffolk County, the recharge of aquifers comes from rain. The principal means of waste disposal is septic systems. Only 15% of the population is sewered, and sewers are, in general, expensive. So far, sewers have been extended to the areas with population densities of five persons/acre or more. Extensive use of on-site systems poses the problem of groundwater contamination. Nitrate contamination of wells has resulted in abandonment of wells. Studies indicate that 30% of the nitrate in the aquifer may be derived from septic systems. Hence, the objective of the study is to develop a no-maintenance, simple, on-site system for denitrification.

A full scale system was developed. The system consisted of a septic tank and a tile field. The unsaturated zone below the tile field provided nitrification. Below the

tile field a pan filled with gravel was used as a denitrification unit. Methanol was added to the pan at the leachate entrance point. A fiberglass shield was placed over the pan to prevent short-circuiting and by-pass of the leachate from the denitrification unit. Several monitoring locations were established.

Results showed that about 80% of ammonia nitrogen was nitrified in the first two feet of soil and the pan provided the opportunity for denitrification. However, the mounding of leachate on the shield resulted in its spillover from the sides. The spilled leachate by-passed the denitrification process. This explained the erratic nature of the data in the pan. Also, the upper layer of the denitrifying pan was aerobic due to excessive amounts of O_2 in the soil profile.

Due to lack of funds, this experiment has been abandoned. The second phase of the study will take care of these problems and will result in the establishment of a design criteria.

In discussion from the floor, Lesouef (France) asked about the cost of this system, source of excessive amounts of oxygen, and consistency and present performance of the nitrifying system.

Andreoli noted that O_2 supply was abundant; in fact, the upper layer of the denitrifying pan was aerobic and this surprised the authors. O_2 availability was of concern and was the reason for choosing the shallow tile system in Long Island. Extra cost of this system was associated with digging one more meter of ground. He noted that until six months ago, the system was performing well. Initial methanol addition took place in October 1976. He went on to state that they are looking into another source of carbon, as residents cannot be expected to add methanol. The alternative sources being investigated are sulfur, sewage and bog.

Aulenbach (USA) noted that sewage is an alternative. Land application studies at Lake George show total denitrification at depths of 15 m due to anoxic conditions. Ahmed (USA) noted the work of R. Laak of the University of Connecticut and the use of gray water as a source of carbon. He also mentioned the denitrification system installed in a condominium complex in Woodbury, CT.

Andreoli noted that gray water as a source of carbon is one of the options being considered for the second phase. The second study phase includes several designs. Compared to

the current practice of leaching pools, the cost of the modified design will be twice as much — however, this is still cheaper than the use of sanitary sewers.

IV. CRITIQUE OF SESSION

The subject matter — disposal of phosphorus sludge, landfill leachate treatment and groundwater contamination due to waste disposal — is of current concern in the USA, Canada, and other developed countries.

With respect to Paper No. 59, it was unfortunate that the study lacked an assessment of the role of pH on metal uptake. Even if disposed sludges are made neutral as was the case with iron sludge, external factors can change the pH of the soil system. Acid rain is an example of such an external factor. One also needs to address the problem of the maximum sludge acceptance capacity of a soil.

Paper No. 60 presented data from 15 landfills in West Germany. The paper, however, failed to demonstrate how the proposed aerobic processes can cost effectively treat the leachate whose characteristics and production rates are variable. The degree of uniformity in leachate from 15 different landfills was rather surprising.

Paper No. 61 presents a simple, practical analysis of a groundwater contamination problem due to oxidation ponds. However, the paper and subsequent discussions failed to present a clear comprehensive picture of the total processes in the aquifer including aerobic-anaerobic decomposition, nitrification-denitrification and changes in the physical characteristics of the aquifer due to biological processes.

Paper No. 62 presented data from a full-scale on-site denitrification system. Additional experience is necessary to assess the practicality of the proposed system. The need for such a system, however, cannot be overemphasized.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The papers in this session dealt with a subject matter which is of immediate concern in the USA, and, as such, all of the papers will be valuable for American research engineers and scientists.

Use of phosphorus sludge as a resource, quite possibly as a source of phosphorus, needs to be studied along with the other effects of this practice on crops, cattle and

humans as subsequent consumers of the agricultural products. The role of external factors, such as increased acidity of rain on metal uptake by crops, needs to be studied.

It is anticipated that in the USA, eventually some landfills will need to be sealed and leachate will be required to be collected and treated. Leachate treatment, hence, will remain a subject of research in the coming future and, as such, Paper No. 60 and other work in West Germany could be of use in our own efforts to develop cost-effective leachate treatment systems.

With recent strong emphasis on lagoons and other simple land disposal alternatives for domestic wastewater treatment, the actual field experience noted in Paper No. 61 should be valuable to researchers. The Dan Region experiment is a rather elaborate wastewater reclamation project and the results from this project should be studied for its utility in the USA.

Paper No. 62 addresses a critical issue — use the cheaper on-site disposal alternative yet still prevent the problem of nitrate contamination. Again, recent emphasis on on-site systems (innovative/alternative systems under the 201 Plan) makes this research very pertinent.

I. SESSION

- A. Day: Wednesday, June 25, 1980
Hall: C
Time: 2:00 to 2:45 pm
- B. Theme of Session: Effect of Toxicants on Methane Fermentation

II. REVIEWER

- A. Name: Frederick G. Pohland
- B. Position and Affiliation: Professor, School of
Civil Engineering
Georgia Institute of
Technology
Atlanta, GA

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 63: "The Response of Methane Fermentation to Cyanide and Chloroform" J. Yang, R. E. Speece, G. F. Parkin, J. Gossett and W. Kocher (USA)

This paper was concerned with the effect of the toxicants, chloroform (CHCl_3) and cyanide (CN^-), on methane fermentation of acetic acid ($3.3 \text{ kg/m}^3 \cdot \text{day}$) with enrichment cultures in serum bottles and with anaerobic, submerged filters. These systems demonstrated that methane formers could acclimate to CHCl_3 and CN^- concentrations approximately 50 times otherwise inhibitory in unacclimated cultures. Within the ranges of observation, cyanide toxicity was readily reversible whereas chloroform toxicity exhibited some irreversibility and only partial recovery of the treatment system. The anaerobic filter in either case was more capable of handling slug doses of toxicants, primarily because of its inherent solids retention capability.

With acclimation, anaerobic filters could tolerate 20 to 40 mg/L of cyanide and chloroform without inhibition of methane production. One-day slug doses of 750 mg/L CN^- and 200 mg/L CHCl_3 resulted in an initial severe inhibition of gas production and decreased COD removal but recovery was possible within four days. The toxic effect of cyanide could be reduced by the addition of hydroxylamine, cysteine, thiosulfate or dithionite.

The paper was presented by G. F. Parkin and basically addressed three issues: (1) Patterns of recovery of methane fermentation after exposure to toxic materials; (2) Degree of acclimation of methane formers to toxicants; and (3) Reversibility or irreversibility of the inhibition. These three issues were provided focus by a discussion of serum bottle and anaerobic submerged filter studies, first with chloroform and then with cyanide. The base substrate for the studies was acetic acid and a nutrient salt solution. Activity of the methane formers to the toxicants was illustrated by changes in gas production and effluent COD with time and dosage. A solids retention time (SRT) and temperature of 50 days and 35°C, respectively, were employed.

Acclimation to both chloroform and cyanide was shown by a series of illustrations of effects of toxicant on the indicator parameter of choice. Recovery was usually preceded by a lag, the extent of which was determined by the concentration of toxicant and/or the past history of acclimation. Toxicant levels of 300 mg/L and 50 mg/L for chloroform in slug and continuous additions, respectively, necessitated the greatest recovery periods (30 and 45 days). Similar results were also observed for cyanide where 30 mg/L continuous and 750 mg/L slug loadings resulted in dramatic decreases in gas production and COD removal. From these results, inhibition of methane fermentation was considered to be more reversible with cyanide than with chloroform and that with cyanide, the addition of reducing agents such as hydroxylamine could shorten the time during which the effects of inhibition were observed.

The invited discussor, A. Molof (USA), recognized the authors' focus on the beneficial use of anaerobic fermentation processes for waste stabilization particularly for energy recovery and when potential toxicants exist. However, it was considered unfortunate that the toxicants, chloroform and cyanide, were not measured directly and that their biodegradation characteristics were not established. Moreover, other parameters such as pH were considered of importance in more completely assessing the effect and fate of toxicants during methane fermentation.

Particular emphasis was placed on the actual chloroform residual in the liquid phase for the various slug doses at the time of recovery of gas production. Calculations indicated that, based solely on dilution (no biodegradability or volatility), a minimum chloroform concentration of 10-12 mg/L in the liquid phase would need to be reached before gas production could be expected to resume. Similar results were claimed for the effects of cyanide although the authors noted

a difference with faster recovery times. This prompted the question as to the relative sorption of either cyanide or chloroform within the biomass. Without concentration data, no estimate of effect could be made.

Regarding the conclusions on reversibility and irreversibility, the discussor submitted that, since the experiments were not allowed to continue to a point where final results could be observed, the comment on "partially reversible" was considered moot as was the presumption of plug flow conditions. Moreover, although the authors mention, in addition to hydroxylamine, three compounds containing sulfur as effective in decreasing the tenure of toxicity of cyanide, no data were presented. However, the discussor, through personal experience with sodium thiosulfate and sodium thioglycolate, indicated that sulfur compounds can effect a reduction in toxicity of heavy metals and that if sufficient dose is used, reversible inactivation would result.

In replying to the formal discussion, Parkin prefaced his remarks by emphasizing the intent to refute the unreliability of anaerobic methane fermentation as espoused by many in the field and to indicate that the work presented was only part of a larger effort being conducted at Drexel University to catalogue the response patterns for some 20 to 30 different types of toxicants from heavy metals, to sulfur compounds, ammonia and petrochemicals. It was also not intended for the paper to stand by itself but to later fortify it by publication of additional supporting data.

Although it was admitted that measurements for either cyanide or chloroform were not made, pH was consistently near neutral in all experiments with high alkalinity which would cause both cyanide and acetate to be in the ionized forms thereby precluding toxicity by unionized species. In addition, it was agreed that dilution to a constant concentration at which the system recovered under various slug loadings did probably occur. This was also observed in other studies for different toxicants. However, if the slug loading exceeds that concentration permitted by dilution, then the concentration at recovery may be reduced, i.e., with ammonia, recovery for a slug loading of 15,000 mg/L was lowered from the usual 6000 mg/L to 900 mg/L.

Regarding the relationship between acclimation and metabolism, no firm evidence was available. But, it was suspected cyanide might also be metabolized; with other materials, methane formers seem to acclimate. In that sense, reversibility was considered a possible unfortunate choice. However, it was emphasized that the important point was what happened to recovery time after the toxicant was removed from

the liquid and that the results observed between cyanide and chloroform were also shown in the case of ammonia in other studies.

C. O. Parker (Australia) opened the floor discussion by relating experiences with practical applications of methane fermentation of lye-treated potato processing wastes. Apparently, a fumigant material which was introduced to retard sprouting of potatoes (SPCC) had the possibility of crystallizing and concentrating sufficiently to inhibit pilot-scale digestion studies. The suspected concentration was 50 mg/L.

T. Nolke (Japan) commented on the need to express results in terms of mixed liquor volatile suspended solids (MLVSS) because changes in biomass will similarly change the fate of toxicants. Moreover, personal studies had indicated washout of biomass in chemostat experiments in three to four days as opposed to the seven days indicated by the authors for formaldehyde. Comments on the condition of the biological slimes during chloroform and cyanide loadings of the anaerobic filter and the effect of hydroxylamine on cyanide toxicity were requested.

In reply, Parkin agreed that wash-out times were longer in these studies than the two and one-half to four days reported by others and attributed the higher values to probably variations in bacterial populations. The comment on the need to measure biomass concentration was accepted as germane with the indication that other studies had indicated that doubling the volatile solids concentration reduced recovery time. The reducing nature of hydroxylamine was considered effective in decreasing the toxicity of cyanide.

A. Wheatland (UK) commented that the 1 mg/L chloroform in many sewages may concentrate in the greasy material and result in higher concentrations in the sludge at a sewage treatment plant. This concentration has detrimentally affected sludge digestion. An example cited with pentachlorophenol manufacturing residue of less than 1 mg/L inhibited digestion and resulted in the need for costly removal of the sludge from the digesters.

Parkin responded that some results have indicated similar experience with 1 mg/L of toxicant or less. These concentrations could be accepted if acclimation is permitted. Every system is likely to respond differently. The relatively long SRT provided by certain anaerobic treatment systems, i.e., the submerged anaerobic filter, the fluidized bed anaerobic upflow process, the anaerobic sludge blanket process and the anaerobic rotating biological contactor, makes these

processes particularly attractive in cases where industrial toxicant loadings are anticipated.

H. Pal (Kuwait) introduced experiences with aerobic treatment of combined refinery and urea manufacturing wastewaters containing NH_3 , H_2S , urea and chromium. Further studies with cyanide indicated that a substantial effect on the degradation process was noted in batch mode whereas when operated continuously, no effect was manifested. The authors were requested to comment on possible similar effects with anaerobic treatment.

Parkin replied by describing anaerobic treatment investigations with a waste containing 1000 mg/L phenol, 2000 mg/L ammonia and 5 mg/L cyanide which has been successful. It was suggested that anaerobic treatment be attempted.

IV. CRITIQUE OF SESSION

The session was well managed with good audience response engendered by a provocative presentation on methane fermentation and the effect of wastes containing potential inhibitors. The authors of Paper No. 63 presented only part of a much more detailed study and, therefore, risked some of the apparent errors of omission. This served to catalyze a productive and informative discussion which emphasized the complexity of both the array of toxicants that exist as well as their behavior within the anaerobic treatment process. Being the only paper of the session and the only one dealing directly with methane fermentation at the Conference probably reduced some participant interest and the paper's competitive stance with concurrent sessions. However, the session discussion as well as those participated in outside of the meeting room indicated that potential interest in anaerobic waste treatment, particularly for industrial wastes where direct energy recovery can be achieved, is high. The existence of potential inhibitors in many industrial wastes makes such an application considerably challenging. Other investigators, including this reviewer, are investigating the possibility of using anaerobic processes for treatment of complex industrial wastewaters containing toxicants as a means of pollution control and energy recovery. In that sense, the authors' studies are timely and pertinent to the emerging technological applications in the field.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Since the studies reported were performed within the USA with support from the Federal Government, they are of priority concern to the overall water pollution control

effort. The control of toxicants from industry and the development of effective treatment processes that promote energy conservation are definite contemporary challenges. Anaerobic treatment processes have been and are continuing to be adapted to accommodate this challenge and recent emphasis on anaerobic upflow processes (filter, fluidized bed, and sludge blanket) as well as the anaerobic rotating biological contactor attest to these developments. These developments should be encouraged and studied on appropriate laboratory-, pilot- and full-scale applications. In addition, possible pretreatment techniques for modifying otherwise toxic constituents in industrial wastewaters should be investigated. The reactivity and ultimate fate of toxic component in anaerobic treatment processes should be defined together with the benefits of energy recovery.

I. SESSION

- A. Day: Thursday, June 26, 1980
Hall: C
Time: 9:00 am - 12:30 pm
- B. Theme of Session: Water Quality Modelling and Management

II. REVIEWER

- A. Name: Roger A. Minear
- B. Position and Affiliation: Professor of Civil Engineering
Dept. of Civil Engineering
University of Tennessee
Knoxville, TN

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 64: "Least-Cost Optimization for Area Wide (208) Wastewater Management Using Mixed Integer Programming," by K. J. Phillips, S. R. Kellogg, E. J. Beltrami and T. O. Carroll (USA)

The paper dealt with the regionalization of 25 wastewater plants in Nassau County on Long Island, New York. A diversion facility matrix was assembled among the individual plants, not all of which were capable of accommodating diversion due to constraints on expansion and other aspects. Even so, the resulting possibilities were 600,000 in number (reduced from billions) which would be impossible to manage by hand. The authors presented a computer technique capable of evaluating this number of alternatives, mixed integer programming, which uses an algorithm referred to as the branch and bound method. This method partitions the feasible region into decreasing subregions (branching) and then removes those (bounds) that would not lead to an optimal solution. The objective function presented minimized total costs which were comprised of diversion costs plus treatment costs. The formal presentation provided little real detail about the process; rather, it gave a qualitative overview and then presented the final solution of the best combination of plants on a least-cost basis that yielded the best overall water quality. Plant sizing was a definite factor in the process.

L. Ellis (UK) was the first formal discussor for this paper and strongly supported the model approach to this type of problem but emphasized the need to get the correct data into the model. A number of points were made in the discussion. The discussor felt the authors had underplayed the role of engineering judgement and felt the details of the matrix preparation were important. He pointed out the need to account for long term changes, land use planning, future environmental and energy costs, diseconomies of scale, especially with regard to sludge disposal at large plants. Concern was expressed for how the authors anticipated future development and the general application of standardized EPA cost data. Ellis also inquired about the solution sensitivity to costs after initiation of the first stage and stated there was a need to translate the procedure to practical use.

Phillips (USA) replied that the matrix was extremely important in the development and represented a clear concept of the desired investigation. They had detailed cost estimates and preliminary diversion information from detailed engineering studies at the outset, including information on the willingness of other plants to accept diversions. Regarding land use planning, long term changes were not included, Phillips contended that 90% of the land was in final land use. This ambiguity was not elaborated further. Also sludge disposal was not included because the county has a composting plan and thus only a minimum impact of sludge considerations was expected. The EPA standardized cost data were refined for local conditions.

The second invited discussor, Bonsall (UK), expressed concern about indiscriminate application of the procedure and felt it served only for broad planning. He indicated that a rigorous sensitivity analysis was necessary relative to cost and assumptions among others. He also asked why in some cases there were negative fixed costs. Several other concerns were expressed about cost slopes remaining constant upon diversion changes, basis for diversion diameter calculations and equipment replacement factors.

In discussion from the floor, Stegmann (South Africa) had similar concerns and felt the technique was limited to defining broad directions to take and that though the optimal solutions would be good candidates, there would likely be other solutions requiring additional engineering analysis for the final solution. Ellis (UK), the formal discussor, expressed surprise that the model did not include sludge considerations in general since 50% of treatment cost relate to sludge disposal. He suggested that this factor should feed back to the treatment approach on the front end.

Phillips' responses to the discussion by Bonsall was that the costs were estimated by modeling flows coming into the plant and then calculation of construction costs were used via linear regression to develop the curves. Negative costs were due to existing plant equipment; therefore, it showed as a value added or negative costs. Diameters were determined by using multiples of daily flow and this was done previously by an engineering company for the individual plants. Finally, the plant equipment values were estimated but those for the sewers were not; thus, the model probably needs some fine tuning.

In response to Stegmann, Phillips agreed that the model is a broad planning tool and Nassau County has taken the model results as a first step in its "201 facilities planning" approach.

Phillips agreed with Ellis that the existing model probably could not handle considerations of sludge disposal beyond the specifics of the Nassau County approach.

- B. Paper No. 65: "The Use of the Multidimensional Analysis in the Comparison of the 1976 vs 1971 Seine Basin Surveys," by Y. LeFoll and A. Lesouef (France)

"Two river pollution surveys have been carried out so far in the Seine River Basin (in 1971 and 1976) at 271 sampling points. Twenty-two of these points were monitored monthly over the period 1971-1976. The total number of determined measurements is approximately 110,000.

Methodological aspects of the correspondence analysis used together with classical methods to interpret this mass of data are presented.

Application of the method to the determination of seasonal and annual effects over the period 1971-1976 are more easily shown. For most determinants, the seasonal variations are shown to be more important than the annual variations.

Comparisons of the 1976 vs 1971 surveys are presented. Because of the importance of the seasonal variations, adapted data codification is defined to only take care of the annual differences. Determinants playing a major role in discriminating quality changes are identified. Based on all determinant measurements the 271 sites are classified

into nine groups which represent the nine main types of water quality changes between 1971 and 1976. A map is provided.

An index of the water quality changes is calculated for each of the five sub-basins. The sub-basins are ranked according to the indexes, and this ranking is compared to the ranking of relative pollution discharge reductions which took place during the same period in each sub-basin. A fair agreement exists between the two rankings with one exception which is discussed."

•The authors concluded that the correspondence analysis method provides an effective screening tool to rapidly draw attention to the main aspects when dealing with large numbers of data (as for their study, 110,000 values); they did point out that this approach does not eliminate the need to examine detailed results nor does it supersede traditional techniques of comparison of means, map examination, river profiles and use of deterministic models. The method is an excellent tool for calculations of water quality indices without setting standards a priori.

B. Adams (Canada) was the invited discussor. In addressing the two methods, classical analysis and correspondence analysis, Adams pointed out that interpretation must be relative to the study objectives. He had some concern over use of grab samples only at all but 22 stations where monthly samples were taken and that of the 57 determinants, only 22 were measured regularly. Specific questions asked were, (1) How were sites established, locations and number?, (2) How was frequency established?, (3) Would a short term program yield more information?, (4) What would be the similarity of grab sampling at each of the four sampling times? Comments were then directed at the general philosophy of water quality analysis. Given that correspondence analysis is a new and abstract procedure, there is concern with the use of this procedure for drawing conclusions and interpretation especially relative to only four samples per year. Regarding the compound analysis itself, questions were raised regarding classification of dissolved oxygen into 0 or 10 mg/L and nitrate as 10 or 15 mg/L. Why only two categories? Adams felt that the results were only qualitative.

Lesouef (France) responded with some details on the classical vs. correspondence analysis procedures as justification for their selections such as use of yearly mean values, comparison of length profiles and evaluation of parameters at sites in the context of similarities. He did agree that correspondence analysis is qualitative but its use then allows focus on the more interesting aspects in a

quantitative sense, i.e., it allows quick screening of the data base. Regarding the validity of four samples per year, it was pointed out that of the 27 sites monitored, roughly one half were examined monthly; therefore, the sampling was fairly representative.

- C. Paper No. 66: "Combating River Pollution Taking the Rhine River as an Example," by C. van der Veen and J. Huizenga (Netherlands)

The paper dealt with the problems of the pollution of an international river taking the River Rhine as an example. The interests of the various riparian states in the river were discussed and the current state of pollution of the river water and a number of salient points connected with this pollution were described. Furthermore, a discussion of existing international collaboration within the International Commission for the Protection of the Rhine against pollution and the European Communities with regard to schemes and measures to combat riverwater pollution was given. The effectiveness and limits of these schemes/measures were considered and recommendations were made as to possible ways of cleaning up an international river more effectively and more quickly.

In closing comments, the author (van der Veen) said that in river basin management (such as the Rhine but others too) management objectives should be fixed and these should be based on the river water quality. The water quality desired by people in the area should be the main principle (in the treaty these water quality objectives are stated). A change in elaboration of discharge standards is needed because their relationship to river water quality is still unclear. Because public interest is increasing, there is a need to ensure that standards, that is their basis and utility, are clear to the public and politicians. Also, we should seek to keep standards at the natural level rather than tolerate significant deterioration.

Formal discussion was presented by E. Myburgh (South Africa). He noted that much of the data for the lower Rhine exceeded recommended international levels and asked if the fault lay with increasing demand and use of cooling water withdrawal from the Rhine and suggested the need to define power station use effects relative to closed versus evaporative cooling systems in future development. Additional questions dealt with the effects due to parties not faced with concerns of future use of water and on what basis for users were standards set. Myburgh contended that the source is the best place for control and suggested that if the facts were published, the public would do the rest.

van der Veen replied that the answer to the closed versus open cooling systems question would be supplied in the formal written reply. He acknowledged that the discharge standards issue was an important one at the moment on the Rhine and in Europe in general. When similar or equal standards are applied in heavily loaded areas, the resultant water quality will be less. This is a problem and must be dealt with by the International Rhine Commission (implying that it is not currently being handled).

In a somewhat long comment from the floor, one of the founders of the Rhine Commission, Coin (France) gave a history of the Rhine Commission's three phases and then turned to the problems today such as the drafting of a chemical pollution agreement in parallel to the Common Market as opposed to prior concerns on the salt level. He emphasized the difference between water quality and discharge levels.

Mussing (Germany) asked what state of water quality is desirable and practical and how would it be reached in practice? He felt that in spite of all measures, the Rhine will be endangered.

Carroll (Canada) asked if there were some central authority and also if there were any computer modeling activities. In his reply, van der Veen responded in a general sense, returning in part to comments by Quant. Salt problems were avoided because they are political rather than technical. He reiterated Mussing's point that we must not accept pollution of river water since we have the technology to prevent it. Regarding the mechanism, he stated that if the goal is of an intermediate nature, it is difficult to come to a clear solution as to what that intermediate goal should be. Conflict of interest and confusion will arise which is of no benefit to anyone. Instead, industry needs notification of a goal and that should be as near the natural level as is economically possible but this takes time.

- D. Paper No. 67: "The Application of the Biocenotic Model for the Prediction of the Effects of an Impoundment of Flowing Water," by M. Boes (Germany)

The Biocenotic model of the "Landesanstalt für Umweltschutz Baden-Württemberg" was used for the prediction of the effects of a possible impoundment of the Murg River, which will result from the building of a planned impoundment at the Rhine. This model is capable of forecasting the oxygen budget and the organic pollution of flowing waters. First, the structure and behavior of the model were described. The computations treated the following: the behavior of the

oxygen consumption of the "consumers," including the respiration of the producers, the consumption of deposited sludge, the oxygen production, and the physical aeration in the unimpounded part and in the impounded part of the Murg; the dependence of the oxygen budget on the flow rate, temperature, and solar radiation; effects of advanced waste water purification or artificial aeration; diversion of the Murg into the tailwater of the impoundment.

In the case of an impoundment of the Murg, the results showed that further advanced waste treatment stages should be built for the larger sewage treatment plants. As an alternative, the backwater should be artificially aerated. From the point of view of water quality, a diversion of the Murg River is recommended.

The model was presented as a mechanistic model which traces back to fundamentals. It is claimed to handle a wide range of flows yet reduces data requirements. It contains a simplified organism structure, three autotrophs and six heterotrophs in the food chain, a photosynthesis/respiration component, sedimentation, sludge O_2 demand, O_2 dynamics and energy input factors. Segments are independent with a transport interlinkage. The model relates to secondary pollution effects which are important to impoundments.

Herricks (USA) in formal discussion addressed the modeling procedures used by requesting clarification in the understanding of the model. He expressed apprehension in use of simple models and a lack of sensitivity analysis. Use of one-dimensional models was deemed acceptable for rivers but not for lakes. The mechanistic components were questioned, particularly consumer migration. The formulation of the five-day BOD vector from ultimate BOD was uncertain from the presentation. Model calibration and validation clarification was sought.

Boes responded that the model is dimensional and dynamic except flow is not a function of time. It was acknowledged that the model cannot be used for lakes, only rivers and impoundments with a minimum flow requirement for application. Better definition of the model is contained in the literature. The model does not use ultimate BOD to calculate five-day values but uses respiration data to artificially determine five-day BOD from specified factors related to dissolved organic matter, bacteria and plankton populations. Verification has been achieved on German rivers (small compared to many in the USA) and "good" results were obtained (not explained). The model maintains the same structure and constants for all rivers. Some sensitivity

analysis has been done and while variations are fairly large they are within limits of determining river geometry.

IV. CRITIQUE OF SESSION

Paper No. 64 was basically an applied engineering study using the tools of operations research. The basic criticism of the work was its lack of capability to handle sludge disposal costs outside of the narrow range pertaining to composting by Nassau County. However, an effective way of handling and optimizing solution of a large number of alternatives was presented and should be of future value. Paper No. 65 presented a novel approach to data analysis.

Paper No. 66 provided interesting insight into downstream water quality degradation and the problems associated with achieving water quality objectives (and even setting these objectives) across international boundaries.

Paper No. 67 seemed limited in its application. No sedimentation compartment is factored into the model in the dynamic settling sense and the size of rivers for which it has been validated limits its application.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Paper No. 64 relates to activities in 208 and 201 management and planning areas and should help serve to stimulate changes in the procedure to make it more widely applicable to 208 and 201 activities nationwide. The application of Paper No. 65's approach to data analysis should be given universal acceptance. This work was not immediately apparent from the presentation and subsequent discussion.

In Paper No. 66, the analysis of deterioration applies to many rivers in the USA where similar effects have been seen. The multinational aspect is not particularly relevant to the USA in the same context relative to industrialization in spite of the Colorado River situation.

The model in Paper No. 67 like any other model may have application to USA rivers and impoundments if the boundary conditions can be satisfied and acceptable results are obtained. Users of any model must assess this aspect.

I. SESSION

- A. Day: Thursday, June 26, 1980
Hall: C
Time: 2:00 - 2:45 pm
- B. Theme of Session: Relationship between Urban Runoff Quality and Some Hydrological Parameters

II. REVIEWER

- A. Name: Frederick G. Pohland
- B. Position and Affiliation: Professor, School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA

III. DESCRIPTION OF SESSION PAPERS

- A. Paper No. 68: "Urban Runoff Quality in Finland and its Dependence on Some Hydrological Parameters," M. J. Melanen and R. H. Laukkanen (Finland)

This paper reported on progress of an existing three-year storm water project in Finland which has studied the relationship between storm water quality and its dependence on climatic conditions and catchment-related factors. Seven urban test sites have been identified in four regions of Finland and include single family residential, traffic (motorway), and industrial areas. Data on rainfall intensity (maximum), duration and quantity, runoff volume and maximum flow rate during sampling, length of preceding dry period, and amount of preceding rainfall generating an observed runoff were presented for the summer-autumn period (May - October). Runoff quality parameters dealt with in the paper included suspended solids (SS), BOD₇, COD, total phosphorus (TP), total nitrogen (TN), pH and lead (Pb).

In general, parametric testing was found applicable in statistical analysis of urban runoff quality parameters. Urban storm runoff quality varied widely between and within different urban catchments. Two area-wide categories were defined (suburban residential and others) where significantly different variance occurred. The fraction of the variance of urban runoff quality explained by linear models of the hydrological variables (rainfall characteristics and

antecedent conditions) was low with the best explaining parameter being maximum rainfall intensity.

The paper was presented by M. Melanen and included a statistical analysis of the data based on the Kolmogorov-Smirnov test for normal distribution on data sets varying in size of sample from 8 to 48. Results indicated that SS, TP and Pb were critical to normal distributions; maximum rainfall intensity and length of preceding dry period were critical rainfall characteristics. There was a demonstrated wide variation in runoff quality between areas with pH not correlating with any other tested parameter. In some cases, contradictory results were obtained, i.e., correlations changed from positive to negative with increasing/decreasing number of observations or from one test site to another when the total number of observations was less than 20.

Of the rainfall event-related characteristics, rain volume, rain duration and storm runoff volume during sampling had negative correlations with storm runoff quality parameters. This was considered to reflect occurrence of the "first flush" phenomenon, i.e., during long rainfall-runoff events, low concentrations after "first flush" effectively decreased the composite concentrations. In contrast, dry periods correlated positively with runoff concentrations indicating accumulation of pollutants on the catchment during dry weather. In addition, volume of preceding rainfall had negative correlations with quality parameters because of flushing of catchment surfaces. Growing maximum intensity of the rainfall event and related maximum storm water flow rate tended to increase storm water concentrations.

The prepared discussion was presented by J. Olie (France) who expressed surprise at the positive results and normal distribution of the data. With the limited numbers of analyses, a more skewed distribution was expected and at least 100 analyses on each parameter was believed preferred to make judgements on levels of significance. The discussor, however, recognized the additional effort and costs of acquisition of such supplemental data.

Since storm volume is prone to change, the use of non-linear models was considered more appropriate and attempts were advised to analyze for each rainfall event rather than an average. Results in France along highways were cited as examples of cases where similar results have been obtained. The critique of the session by the discussor was more directed toward the application of the statistical methods used than the data used for the analysis, although some of the data were indicated to be less than representative.

Melanen responded to the discussion first by pointing out a correction to Table 6 of the paper where Pb should be replaced by SS and pH should be replaced by Pb. Then, in defense of the use of the Kolmogorov-Smirnov statistical test, it was contended that the procedure did afford an opportunity to determine whether normal distribution of the data should or should not be rejected. The use of the significance of one percent was related to the recognized limit on number of samples.

It was emphasized that the paper was a first trial with the data, primarily for the first two-year period. Now that a third year of data is available and more data are forthcoming, the analysis can be updated and made more reliable. It was agreed that some of the samples may not have been representative and that "non-representative" samples would be eliminated in future work. Finally, the presenter questioned the ultimate wisdom of efforts to model quality of storm runoff and suggested that pollutant load modeling may be more appropriate. Such studies were also to be included in future work.

IV. CRITIQUE OF SESSION

Only modest interest was displayed concerning storm water quality phenomena and procedures and methods of analysis. There was evidence that the area needs attention, but that its complexity requires a site specific analysis. It is a topic that apparently is being addressed elsewhere but from a water quality-pollutant loading orientation.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Data on urban storm water quality have been developed over at least three years in seven different areas in Finland. These data apparently include not only those parameters discussed in the presentation, but also others such as nutrient species, chloride, sulfate, conductivity, temperature, dissolved oxygen, fecal coliforms and heavy metals. As such, these studies could be a resource for complementary studies in the USA.

Although not finally concluded, techniques for correlation analysis and levels of significance are diagnostic tools for water quality studies throughout the world. Experience in Finland (and France) can provide some judgements on applicable techniques and procedures for similar analyses elsewhere. Data from the studies in Finland may serve to provide complementary confirmation (or contradiction) of results of companion studies in the USA.

I. SESSION

- A. Day: Thursday, June 24, 1980
Hall: Workshop
Time: 3 to 5 pm
- B. Theme of Workshop: Management and Control of Heavy Metals in the Environment
- Convener: Jon C. Van Loon (Canada)
- Panel: D. W. McLeese (USA), J. Kramer (Canada), P. Stokes (Canada), R. Leschber (Germany), J. Patterson (USA)

II. REVIEWER

- A. Name: Dipak Roy
- B. Position and Affiliation: Assistant Professor
Dept. of Civil Engineering
Louisiana State University
Baton Rouge, LA

III. DESCRIPTION OF SESSION PAPERS

No formal papers were presented in the workshop, each member of the panel discussed an aspect of the management, control and effects of heavy metals in the environment. Van Loon (Canada) introduced the panel members and made a brief speech to present the theme of the workshop covering the following points:

Until three or four years ago available data in the literature appeared sketchy and difficult to interpret. He questioned the accuracy of these data and the conclusions based on them. However, in the recent years we have started getting good data. So far, most of the available data report total metal concentrations. The need to find out the form of these heavy metals in the environment was stressed.

McLeese (USA) discussed the effects of cadmium on marine invertebrates. Investigations of the lethal concentration at short- and long-term exposures revealed that lobster larvae were killed by 30 $\mu\text{g/L}$, shrimp and similar crustacea by 2 to 3 mg/L , and adult lobsters by 5 mg/L . Nereidae worms could tolerate concentrations greater than 10 mg/L . Based on these results, he concluded that cadmium

may not pose a big threat to marine invertebrates because cadmium concentrations above 30 $\mu\text{g/L}$ would be very unlikely.

Accumulation of cadmium in marine animals was studied using crustaceans in natural bioassay tests. Analysis of cadmium indicated that there was no significant difference in concentration levels in animals and in sediments. Absorption/desorption of Cd by sediments was reported to be dependent on the cation exchange capacity and organic content. In experiments using two types of natural sediments it was observed that there was no uptake of Cd from one sediment, whereas a slight uptake was observed from the other sediment which had a lower organic content. Accumulation of Cd in animals was dependent on concentration levels in water rather than those in sediment. Accumulation per unit weight of animals was greater for smaller animals than larger animals. No leveling off of uptake was observed up to 30 days. No excretion of heavy metals from animals was observed up to 70 days.

Kramer (Canada) mentioned the relationship between cardiovascular diseases in humans and the hardness of drinking water. It was noted that small increases in metals uptake tend to suppress some diseases. He suggested that parameters like alkalinity and pH may also affect the uptake of metals. At low pH, uptake of metals may be decreased. In that context the question was posed, "could it be that the corrosive nature of soft water is removing heavy metals from food and thereby creating a shortage of heavy metals in the human body?"

Stokes (Canada) discussed water quality criteria based on the toxicity of cations. Hardness of water was reported to affect the uptake of copper. Presence of more than one heavy metal in water may cause synergistic or antagonistic or additive effects. Methods of evaluating toxicity were described using algae as test organisms. Suppression of photosynthetic activity of algae was monitored as an index of toxic effects. Based on their findings she reported that the synergistic effect of heavy metals may not be as important as it was previously thought to be. She indicated that it would be desirable to develop models which would predict the synergistic effect of heavy metals in the environment. Presently, such models are not available but work has started in this direction. Finally, an index to measure overall heavy metal toxicity would be extremely useful. Preliminary results on the use of copper as such an index appear to be promising.

Leschber (West Germany) discussed the presence of heavy metals in sludges. Heavy metals which are removed at

the end of a sequence of treatment create the beginning of a problem in the area of sludge disposal on land. Research efforts have been initiated in Europe at intergovernmental levels to study the effect of heavy metals on soil. Phosphate concentration was observed to be related to heavy metal concentration in sludge.

Patterson (USA) illustrated the technology and management of heavy metals using a hypothetical problem which approximates a real life situation. In a city of one million there could possibly be three separate sources of heavy metals discharged to surface waters. Copper was used as the model heavy metal in the example problem.

a. Domestic Source - Assuming a 100 gpcd flow rate, total discharge of sewage would be equal to 100 MGD. If a typical copper concentration of 0.3 mg/L in raw sewage were used, then following conventional sewage treatment the concentration of Cu in the effluent stream would be equal to 0.075 mg/L (75% of heavy metals are trapped in sludge). If the treatment plant effluent is discharged to surface water, then the above figures add up to a dumping rate of approximately 60 lb/day.

b. Industrial Source - An industrial wastewater discharge of 0.2 MGD was assumed, with a Cu concentration of 25 mg/L in raw wastewater. If no control measure were adopted then industrial discharge would be approximately equal to 40 lb/day. With conventional control technic the Cu concentration in the effluent can be reduced to one mg/L which results in a net discharge of 1.7 lb/day. If advanced control technics are adopted then a further reduction to 0.2 mg/L can be accomplished and the industrial discharge would be equal to 0.3 lb/day. It should be noted at this point that cost of treatment increases sharply beyond the conventional level.

c. Other Sources - Storm water runoff, atmospheric deposition and other sources may lead to an average discharge of 25 lb/day.

The above data can be summarized in a tabular manner:

CONTRIBUTION TO RECEIVING WATERS (lb/day)

Source	No Control	Conventional Treatment	Advanced Treatment
Domestic	60	60.0	60.0
Industrial	40	2.0	0.3
Other	25	25.0	25.0
Total	125	87.0	85.3
% Reduction	---	30.4	31.8

Considering the hypothetical problem, the following points were made: (1) Only a 30 percent reduction in heavy metal discharge to water bodies could be accomplished even if industries are made to pay for the high cost of treatment; (2) Providing an advanced level of industrial waste treatment leads to a high cost of treatment without significant increase in percent removal; and (3) Volume of sludge to be handled increased leading to an increase in cost of sludge handling.

Sanks (USA) initiated the floor discussion by referring to analytical methods for heavy metals, in particular the atomic absorption method.

Stumm (Switzerland) supported Stokes' (Canada) viewpoint of the importance of physico-chemical processes in receiving waters in changing the toxicity of heavy metals. He warned against the trend to increasing concentrations of heavy metals in water bodies which is a direct consequence of increased fossil fuel use.

Neufeld (USA) presented preliminary data from research done by his group on heavy metal adsorption on activated sludge. The rate of uptake of heavy metals was observed to follow a modified form of the Langmuir equation. The rate of uptake of heavy metals was given by the following equation

$$\text{rate of uptake} = Ac^a - \beta \left(\frac{Q}{A - Q} \right)^{\gamma}$$

where,

A = maximum rate obtainable

c = concentration in liquid phase

Q = concentration in sludge

α, β, γ = constants

Presence of heavy metals was reported to affect the flocculation property of sludge and significant deflocculation was observed beyond certain concentrations of metals. Deflocculation was measured by monitoring supernatant suspended solids.

Jenkins (UK) contested the chairman's introductory remarks about the quality of past years' data and the conclusions drawn therefrom. He encouraged the developing nations to continue research activities with less sophisticated analytical tools rather than waiting for those sophisticated tools to be available some day in the future.

IV. CRITIQUE OF SESSION

Various aspects of heavy metals in the environment and associated problems were presented by a panel of distinguished speakers. There were some undue criticisms about the quality of past works which were rightly repudiated by others.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

An NSF-ASCE study group recently found that the problem of toxic substances, including heavy metals, in the environment should have the highest priority among the nation's environmental research needs. In view of this fact, the theme of this workshop takes on particular significance.

Several aspects of the problem merit special attention. Since the toxicities of heavy metals are generally dependent on the form in which the metal is present, emphasis should be given to finding analytical technics capable of differentiating among various forms.

Development of a reliable index would significantly reduce the volume of analytical work necessary to evaluate the overall toxicity. Use of copper as an index of heavy metal pollution was proposed in the workshop. Further investigations to evaluate Cu and other metals as an index should be undertaken.

The need for models to predict the synergistic effect of heavy metals in water bodies was mentioned. A point was made that synergistic effect of metals may not be as important as was formerly thought; this is an area which needs more

research. The importance of studies of transport of heavy metals in the biosphere was brought up; not enough is presently known regarding kinetics of movement from sludge to soil, for example.

I. SESSION

A. Day: Wednesday, June 25, 1980

Hall: Workshop

Time: 3:00 to 5:00 pm

B. Theme of Workshop: Odour, Airborne Contaminants and
Aerosols from Wastewater Collec-
tion and Treatment

Convenor: H. I. Shuval (Israel)

Panelist: H. Pahren (USA), A. B. Wheatland
(UK), C. Lue-Hing (USA), and
K. Fannin (USA - substitute for
W. Jacobowski)

II. REVIEWER

A. Name: Gene F. Parkin

B. Position and Affiliation: Assistant Professor of
Civil Engineering
Environmental Studies
Institute
Drexel University
Philadelphia, PA

III. DESCRIPTION OF SESSION PAPERS

Since this session was a workshop, no formal papers were given. Each participant gave a ten-minute presentation, the major function being introduction of topics for discussion during the remainder of the session.

In his opening remarks, Shuval (Israel) commented on the historical significance of problems associated with odors and airborne particles and the unscientific nature of much of the data reported on the effects of these phenomena. The purpose of this workshop was to critically review the state of knowledge with regard to odor, airborne contaminants, and aerosols emanating from wastewater treatment and collection facilities and to discuss health and political implications.

Pahren (USA) prefaced his remarks by noting that until recently there had been no systematic investigation of the health effects of aerosols. He reported on five studies completed on wastewater treatment plant operation. The studies used epidemiological techniques such as noting the reported incidence of respiratory and gastrointestinal diseases, reported elementary school attendance, and analysis

of stool, urine, and blood samples for various contaminants such as virus, coliform, and antibody levels. Air samples were also collected and tested for virus particles, coliforms, total viable particles, and mercury, among other things. The only consistent pattern was one of no effect. Contaminant levels in the air surrounding the treatment plants were not significantly higher than background levels. The only discernible differences between control and "affected" populations were a temporary, slight increase in gastrointestinal illnesses for inexperienced wastewater treatment plant workers and an increase in gastrointestinal and respiratory illness for people living within 600 meters of one plant. However, the author noted that in this latter case, the illnesses could also be associated with depressed socioeconomic conditions.

The one general conclusion offered by the speaker was that no microbiological health hazard exists from the dispersal of aerosols from wastewater treatment plants. The potential, however, is there.

Wheatland (UK) discussed the sources, prevention, abatement, and control of odors released during wastewater collection and treatment. Conditions resulting in repugnant odors are usually associated with anaerobic conditions, prolonged retention, inadequate gradients, improper sludge retention, and many other site-specific factors. High-rate filters and aeration tanks are among the worst offenders. Identification of the source and prevention is the best strategy, although this is not always possible. For instance, regulation of industrial discharge to sewers is one proven preventative measure. Abatement usually involves containment followed by scrubbing, oxidation, adsorption, or biodegradation. In some extreme cases, "odor counteractants" may be used to mask the odor temporarily. There exists a need to develop a more scientific means of identifying and studying odors. Such work is now being done in the UK.

It was pointed out by the convenor that the general public will respond to an odor problem more quickly than any other problem associated with wastewater collection and treatment. Thus, odor control is more a sociopolitical problem than a health problem.

Fannin (USA) discussed problems associated with aerosol sampling and analysis. Evaluation of concentrations in aerosols is relatively new technology replete with problems of low and variable concentration levels, "real world" sampling problems such as size, number and location of samplers, and questions concerning data evaluation. Since sampling aerosols involves particle collection, particle

separation techniques such as settling, filtering, impingement, electrostatic precipitation, and cyclone scrubbing were described. The effect of particle size is important in relation to monitoring respirable particles. Large volume air samplers and multiple samplers are usually required due to low concentrations of aerosols. There are many devices available for sampling and analyzing microbial aerosols, but their reliability and precision have yet to be adequately determined. The speaker also commented on a model of aerosol emission that is in the development stage.

Lue-Hing (USA) spoke about the control of aerosols. He and his coworkers in Chicago have been involved in studies with the EPA in measuring aerosol concentration, attempting to delineate the health effects of aerosols, and testing various techniques for suppressing aerosols. Suppression techniques under evaluation include vegetation barriers, partial covering of aeration basins, spraying, addition of a circular canopy over part of the aeration basin, electrostatic precipitation at the end of the canopy, and UV radiation over the aeration basin.

Lue-Hing took a very strong stand on aerosols; he is convinced that aerosols present no health hazard above that of ambient air and that sewage treatment plants do not need aerosol suppression devices. If virus particles are of concern, he pointed to data that indicate that virus counts are very low and, in some cases, not detectable.

According to Rincke (West Germany), the problem in West Germany is associated with dense population and location of wastewater treatment plants in populated areas. The "owner" of the plant is responsible for all disadvantages related to plant operation. For example, odors are a very critical problem because of common practices such as heat treatment of sludges, a process that produces a particularly repugnant odor. Covering of many unit operations and scrubbing of malodorous gases is now practiced because of public relations and political considerations. The following were offered as fruitful areas for research: (1) Means of odor identification/measurement/detection; (2) Minimizing generation of odor; and (3) Optimizing technology for gas treatment.

Strand (Australia) stated that problems in Australia are much different than those of West Germany since population density is not nearly so high. They do have problems with high H_2S levels (10-15 mg/L) and practice control by collection (covering) followed by burning or by hypochlorite oxidation. Anticipated problems with aerosols are controlled by planting trees. Sports grounds are spray-irrigated with

wastewater effluent and bathers at the beach wash off the salty sea water using treated effluent. Thus, health problems associated with aerosol generation do not seem to be of primary concern.

Shuval (Israel) commented that in Israel and in South Africa, up to 10,000 plaque-forming units of enterovirus were detected 50 m from spray irrigation operations.

An unidentified discussor (West Germany) reported on NaCl aerosols from a particular industrial operation and the corrosion problems caused. The question was asked of Pahren if chemical aerosols had been studied. Pahren replied that other chemicals were investigated in one of the studies at Chicago and that levels measured were indistinguishable from background levels.

Fannin (USA) asked Pahren: Is there no microbial health hazard or risk associated with aerosol exposure? Pahren replied that, yes, there was a risk, but no hazard.

Fannin then asked for a definition of acceptable risk. Lue-Hing stated that the city of Chicago has been sued three times by communities alleging health problems associated with wastewater treatment plant operation over the last ten years and the city has won all of them. He feels we are playing with words and that risk is not measurable. He recommends not enclosing aeration basins since the dilution effect will then be lost and concluded by saying that aerosols have been "researched to death" and we need to get on to more pressing public health problems.

Shuval noted that we can set the risk level for aerosol exposure but whether that risk is acceptable is a political problem.

Ramadan (Egypt) feels we need to define how the disease or discomfort is caused, that is, by ingestion, inhalation, irritation of ears or eyes, and we must consider the route, viability of the organism and the resistance of the people. There is a need to determine whether the problem is health or aesthetics. It seemed to me that many of his comments have already been addressed.

Gehr (Canada) agreed with Lue-Hing that aerosols pose no significant health hazard. Odors, however, are a very sensitive problem manifested by public complaints. Vented sewers have had to be covered in Canada and South Africa because of such complaints. In a survey of 100 plants in Ontario, aerobic units seemed to cause more problems by dispersing the odors greater distances from the plants.

Shuval (Israel) commented that aerobic processes are covered in Japan thus minimizing odor problems.

Wheatland (UK) postulated that what Gehr was observing was aerobic dispersion of anaerobically generated odors, a likely possibility.

Lue-Hing (USA) stated that active odor control is being practiced at one Chicago plant (ozone addition) because of the close proximity of some condominiums.

Henry (Australia) commented on the political nature of the odor problem. He feels that there is a correlation between funds allocated for pollution control and the number of votes politicians envision deriving from such action. Odor is a political problem and thus votes may be generated from allocations for odor control.

Henry agrees with Lue-Hing: no more money should be spent on aerosol monitoring and control. There are other, more pressing public health concerns to be addressed.

Bhagat (USA) asked three questions: (1) Is the concentration of pathogens in aerosols a function of geopolitical location (country - USA vs Israel, for example)?; (2) Is there a health hazard associated with release of toxic materials?; (3) Are there any health effects associated with odors? These questions were not answered specifically, but addressed generally in the closing remarks of the panelists.

A discussor from Houston, Texas (USA) pointed out that hydrogen sulfide, considered mainly an odor problem, is a toxic gas at high concentrations and workers must be properly protected. In addition, corrosion problems may be significant at moderate concentrations.

Carroll (Canada) stated that a study of a Winnipeg activated sludge plant with enclosed aeration tanks showed no significant health differences between treatment plant workers and a control group save a slight increase in reported sinus problems for the plant workers.

In closing remarks Shuval (Israel) stated there is a difference in health risk from aerosol exposure for different areas of the world and for different types of treatment facilities. For example, there may be a risk in agricultural settlements located less than 100 meters downwind from spray irrigation systems. However, his conclusions are not yet firm and he feels the area is deserving of more detailed study. Pahren (USA) remarked that volatile organics are

stripped by aeration but there has been no positive correlation with reported health problems. Treatment plants in Japan are not covered to prevent aerosol or odor dispersment but rather to conserve space. Lue-Hing (USA) believes that health risks are accentuated when aeration tanks are covered and that well-run activated sludge systems pose no health risk from aerosol formation. Fannin (USA) agreed with Lue-Hing that negative data are important but that we need to determine a level of acceptable sensitivity for purposes of aerosol sampling and measurement. Wheatland (UK) reiterated his point of need for objective methods for odor measurement.

IV. CRITIQUE OF SESSION

Two major points of discussion were developed during the workshop: (1) Is there a microbiological health hazard caused by aerosol dispersion at wastewater treatment plants?; (2) Odor management is a critical concern. Although discussion was lively and participation excellent, time, unfortunately, did not permit in-depth discussion of either point.

Most people seem to feel that odors, aerosols, and airborne contaminants are operational, not technical, problems. The minimal "scientific" data presented were mostly epidemiological in nature, dealing with public health aspects of wastewater treatment plant operation. All other data were observational.

One school of thought, articulated by Lue-Hing, is that spending money on aerosol research is not something that is cost- or health-effective. In conversations outside the session, it was evident that most people agree aerosols emanating from wastewater treatment plants do not pose a microbiological health hazard. It is difficult to detect pathogen concentrations above ambient levels and even more difficult to develop cause-effect relationships. On the other hand, some people believe that the aerosol-public health connection is site-specific and research dollars should continue to be allocated. An additional consideration, not adequately discussed at this workshop, is the difference between treatment of industrial wastewaters containing potentially toxic materials and treatment of domestic wastes.

The main consensus reached by the workshop and substantiated by conversations outside the session is that odors are definitely a problem. While public health problems are very difficult to assess, odor problems are easy to "identify". Almost everyone agreed that there is a need for a scientific method for odor measurement. A critical question is what odors are acceptable and which ones are unacceptable. The answer is a political one.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION
RESEARCH ACTIVITIES

It would seem as though a major conclusion to be drawn from the workshop is that research addressing microbiological health hazards caused by aerosols is not worthy of major funding. Of course, this does not mean that operation of wastewater treatment plants cannot result in public health problems, only that aerosols are a minor concern. Other areas of public health concern are more critical, for example, fate of priority pollutants and disinfection of effluents. Potential problems may be magnified if unit operations are covered or certain types of wastewater treatment facilities are located in densely populated areas.

This workshop graphically pointed out that, from the public's point of view, efficiency of wastewater collection and treatment can be determined by the presence or absence of unpleasant odor. No new technology was offered and perhaps none is really needed. Instead, the call was for proper consideration of odor prevention and control when developing design and operational strategies. A more unbiased method of odor measurement and optimization of odor removal processes would be helpful. The public must be made to realize that odor control may be expensive.

I. SESSION

- A. Day: Thursday, June 26, 1980
Hall: Workshop
Time: 3:00 to 5:00 pm
- B. Theme of Workshop: Groundwater Contaminants from
Land Disposal of Residues
- Convener: A. van Haute (Belgium)
- Speakers: J. Verheyden (Belgium), J. Sykes
(Canada), C. P. Young (UK), and
R. Griffin (USA)

II. REVIEWER

- A. Name: Kevin J. Phillips
- B. Position and Affiliation: Principal Environmental
Management and Engineering
164 Main Street
Huntington, NY

III. DESCRIPTION OF SESSION PAPERS

As this session was a workshop, the formal papers that were presented were for the purpose of introducing a topic for discussion rather than for the presentation of research results.

van Haute introduced the topic and suggested that the purpose of this workshop be to promote informal discussion of the subject and to identify any further areas of investigations. van Haute felt that this was a very timely topic as numerous problems have recently surfaced regarding groundwater. He added that soils and aquifers have the capacity to purify water; however, that treatment must be considered in developing groundwater as a source of water supply. He went on to say that groundwater problems, when they do occur, occur for long periods of time. That is, the slow movement of groundwater in the aquifer precludes a quick clean-up strategy and suggests that groundwater aquifers must be protected.

van Haute introduced the four speakers that were giving presentations as follows: Verheyden (Belgium) Sanitary Landfills; Sykes (Canada) Modeling; Young (UK) Fertilizer and

Nitrates; and Griffin (USA) on Polychlorinated Biphenyls (PCB).

Verheyden (Belgium), in his presentation, on "Groundwater Contaminants from Land Disposal of Residues: A Survey in the Province of Antwerp", discussed the problems that Belgium has had with contamination of groundwater (from land disposal of residuals). Verheyden stated that Belgium, which is a very intensely industrialized and densely populated country, disposes of much of its industrial waste by placing the residuals on land with very little protection for the underlying groundwaters. Hence, a study was undertaken to characterize the leachate from 15 landfills. Results indicated that most characteristics of the leachate compared favorably with literature values. No acute toxicity or mutagenic effects were observed. It should be noted that no organic sampling was undertaken in this analysis. Results of this preliminary study of the leachate of a highly industrialized region permitted a better understanding in interpretation of their potential impact on drinking water resources. Although acute effects of hazardous waste have not been found, long-term or permanent damage are a concern.

J. Sykes (Canada), in his presentation of the modeling of contaminant migration from sanitary landfills, took a more theoretical look at contaminants in groundwater. Sykes presented a finite element and a finite difference method for estimating the production, migration, and reactions of sanitary landfill leachate in porous media. The modeling of leachate production rather than input boundary conditions adds creditability to the results. Chemical oxygen demand is modeled using Michaelis-Menten substrate utilization and microbial mass production equations. Coefficients for the model are developed from laboratory studies. Comparison between the model results and laboratory column breakthrough curves were shown to be very good. The degradation of leachate organics at a test site (Canadian Air Force Base in Borden) was analyzed.

For adsorption leachate species equilibrium, two site adsorption models are used. For the migration of potassium in laboratory columns it was found that the two site models provided the best results. Extension of the model to field conditions was undertaken with potassium transport at the Canadian Air Force Base in Borden. Chloride migration at this site was also investigated. For both chloride and potassium model results are favorable. This work demonstrates the utility of modeling in the prediction of groundwater contaminant migration. Through the use of independently determined parameters the necessity for model

calibration is greatly alleviated. Further, the minimization of calibration helps in the validation of the model.

Young (UK), in his presentation on the distribution and movements of solutes derived from agricultural land in the principal aquifers of the UK with particular reference to nitrate, discussed agricultural practices and their effect on groundwater contamination. Young presented an extensive site investigation in the two principal aquifers of Great Britain; the chalk and triassic sandstones. Investigation revealed a correlation between high concentrations of nitrate and other nutrients in the aquifer directly beneath farmlands in contrast to low nitrate concentrations directly beneath permanent grass and woodland. Young postulates that higher leaching losses under the farmland results from the increased mineralization of soil, organic material and crop residues consequent upon regular cultivation.

Griffin (USA), in his presentation on the movement of polychlorinated biphenyls (PCB's) and other persistent compounds through soil, discussed the physical and chemical reactions of these molecules as they passed through porous media. The adsorption and mobility of PCB's, polybrominated biphenyls (PBB's), and hexachlorobenzene (HCB) were studied under laboratory conditions. The adsorption of PCB's, PBB's, and HCB by soils and by carbonaceous adsorbents from aqueous solutions and organic solvents could be described by the Freundlich adsorption equation. All three compounds were found to be strongly adsorbed by the carbonaceous adsorbent and by the soil materials. There was a very high direct correlation between total organic carbon of the soil and the amounts adsorbed. No measurable adsorption of PBB's or HCB by soils occurred from organic solvents. Concentrations of PCB, PBB, and HCB in five soils were measured with several different leaching solvents using a thin layer chromatography technic and column leaching studies. The three compounds remained immobile in the soil when leached with water or landfilled leachate but were highly mobile when leached with organic solvents. Mobility was proportional to the solubility of the compounds in the leaching solvent and to the soil organic matter content. It was concluded that these three compounds would not move readily through the earth material leached with water or aqueous leachate but that they were highly mobile in organic solvents. Significance of this study is that PCB's deposited in landfills for many years are not that mobile under normal circumstances. That is, unless there is an organic solvent putting them into solution they will be adsorbed by the soil matrix.

Young (UK) posed a question to Verheyden regarding spontaneous combustion in landfills. Verheyden's response was that burning was not permitted in landfills. However, where spontaneous combustion occurs no action is taken other than putting the fire out. Verheyden went on to state that Belgium's primary means of treatment was to pump this water out of its pooled area and treat it with calcium hydroxide. Young asked another question regarding the movement of methane. Verheyden responded by saying that not much experience or research effort has gone into identifying methane movement in Belgium.

Veits (West Germany) asked two questions of Young. The first was, did the United Kingdom experience any methemoglobinemia and second, could animal decay and animal waste products interfere with the presented nitrate data? Young's response to the methemoglobinemia question was that there were certain cases that have been documented for methemoglobinemia but there has been no complete study on the subject in the UK. Young referred Veits to several Israeli studies that he knew about. Young's response to the animal decay question was that it was difficult to take this into account because it is a local phenomenon but could be significant in the development of their transport model.

Perrin (USA) questioned Griffin as to whether or not plants uptake these trace organics. Griffin's response was that compounds do adsorb on the surface of the plant root; however, they do not travel into the plant itself. However, certain plants such as carrots, uptake the organic directly into the tissue.

van Haute raised the question to Verheyden of whether or not it was advisable to have the treatment plant near the sanitary landfill. Verheyden's response was, "yes," and this would be preferable so that treatment could be performed right on site. Verheyden went on to say it was better to pollute the surface water bodies rather than the groundwater because it is almost impossible to clean up the groundwater after it has become polluted.

Stickmen (Austria) summarized some of the comments that had previously been made regarding the problems of leachate. He suggested that sanitary landfills be designed differently, so that the bottoms be sealed so as not to allow any leachate to percolate into the groundwaters and so that leachate be collected and treated.

Sykes (Canada) pointed out that the biochemical oxygen demand and the chemical oxygen demand are not problems

in sanitary landfill. The problems come from toxic substances (trace organics and heavy metals) that under certain circumstances will migrate into the groundwater. These substances do not lend themselves to conventional treatment. What normally happens is that they will either pass through a treatment plant or that they will be concentrated in the sludge of the treatment system and if the sludge is not properly disposed of, then it will be recycled back into the groundwater.

Azkona (Spain) posed the question to Young, will future agricultural practices change? Young's response was that some agricultural practices have already changed in the UK: for example, no tillage, no turnover of the land, no plowing in certain areas. This has kept the formation of nitrates and subsequent leaching into the aquifers down to a minimum. Young added that the efficient use of fertilizer can also make a big difference. Similarly, efficient timing of fertilizer application when the plant is at its maximum growth potential. This can help the nitrate balance as well as save the farmer money.

Hall (New Zealand) asked the question of Young, does animal waste contribute to the overall nitrogen balance in his studies? Young's response was that animal waste could produce significant local concentrations of nitrogen; however, his study was more regional in scope and animal wastes were not accounted for.

Hall (Malaysia) asked Young whether or not there was a significant swine industry in the UK and whether or not the waste from the swine industry could be disposed of on agricultural land. Young's response was that the UK has been spreading pig waste on the land for several years. The swine waste is high in BOD and high in copper; the soil matrix removes most of the contaminants and, hence, land disposal of the pig waste has not really been a problem.

Ramadam (Egypt) asked Griffin whether or not the accumulation levels of PCB's in the soil will lead to bioaccumulation in the biosphere. Griffin's response was that bioaccumulation has already occurred and is a definite problem. The same factors that cause the PCB's to be held by the soil are those factors that cause the bioaccumulation. The chlorinated hydrocarbons are not degradable and, hence, they persist until an organism comes along and ingests them where they will accumulate in the fatty tissue.

IV. CRITIQUE OF THE SESSION

Suggested topics for further research included full delineation of groundwater contaminants from a problem/cause standpoint, further investigations as to the nature, characteristics, and reactions that occur in porous media to determine exactly how the contaminants move; work on adsorption and chemical reactions of the soil and soil microbiology in the degradation of toxic substances such as polychlorinated biphenyls and its derivatives; additional work in the area of regional aquifer planning to combat the problems of nitrate pollution; and, finally, more work in the area of treatment of landfill leachate and treatment of aquifer contamination.

Informal discussions with presenters at the conference proved valuable in their further explaining some of the typical problems they had to overcome in order to do the research that they are presenting today. For example, Sykes spoke of the difficulty in obtaining accurate data for groundwater modeling studies. Sykes mentioned that it was not only difficult to obtain but very costly.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

This workshop was intended to introduce topics of concern and explore more fully their nature and solution. The topic of PCB's migrating through the soil is of extreme importance to the USA groundwater pollution problems. The implication here is that the PCB's that are so widely used in industrial processes have been deposited in landfills all over the USA may not move very far through the unsaturated zone because their migration is significantly stopped by the soil matrix.

Sykes' research on the migration and movement of contaminants in porous media is extremely important in the identification of contaminant plumes. For example, in cases such as the "Love Canal" in New York State, the identification of the contaminant plume, where it will move, how fast, and what concentrations are likely to occur are extremely important in devising alternatives to treat the contaminated groundwater.

Verheyden's work on establishing characteristics for contamination from landfill leachate in Belgium is extremely important due to the variability of landfill leachate in the USA. If more information can be obtained on the sources of waste that go into landfills and the characteristic leachate

that comes out of it, much more will be understood of the nature of leachate in the USA.

Finally, Young's presentation on fertilizer use and resultant nitrate contamination is extremely important especially in areas such as Long Island, New York or Cape Cod, Massachusetts. Here, as elsewhere, water supply is the groundwater and increasing levels of nitrate in wells have shut down approximately ten percent of the operated wells on Long Island.

CHAPTER III

OVERVIEW OF PERTINENT CONFERENCE DEVELOPMENTS

In this chapter, pertinent developments at the Conference as reported by individual participants are briefly summarized and categorized. The chapter represents primarily a summary of Chapter II. However, the chapter also contains a summary of other observations made by individual participants regarding international developments of potential interest to EPA which did not emanate from the formal program of the Conference.

Developments at Formal Sessions

This section highlights the individual reports contained in the previous chapter by reviewing the more significant observations and conclusions according to various categories of water pollution research interest. In each case, comments are identified by the paper number or workshop title to which the observations relate. Comments included here may not necessarily be contained in the formal papers but may have developed from discussions at the Conference. Paper numbers and workshop titles are included to facilitate reference to the more extensive analyses of Conference developments included in Chapter II. By referring to the paper or workshop of interest in the Table of Contents and Key to Reviews, the location of the corresponding discussion in Chapter II may be determined.

Modelling of Lakes --

The use of vertical diffusion coefficients based on the transport of heat as described by the flux gradient method has limitations and should be used with caution (Paper No. 49, Netherlands). Improved methods of describing vertical mass transport are available which consider wind-induced entrainment and diffusive transport; they require no additional data. There are needs for additional conceptual research in this area.

Nutrients budgets are powerful, relatively simple, and essential tools in managing eutrophication problems (Paper No. 50, USA). The importance of direct atmospheric inputs of nutrients and other pollutants to lakes can be great, and measurements are needed. Significant problems still remain in

modelling water quality in lakes for both steady and nonsteady states. Both new concepts and new data are needed.

There is a worldwide interest in water quality modelling. Empirical nutrient loading models have been valuable in managing eutrophication, but have important limitations. As attention shifts to new pollutants, the potential value of models which can incorporate significant physical, chemical, and biological processes into predictive models that are less empirical than present efforts becomes more apparent.

Pathogen Removal --

C. albicans and acid-fast bacteria were evaluated and indicators of pathogenic organisms (Paper No. 52, South Africa). The idea was to avoid expensive measurement of viruses. Incidentally, without chlorination after primary clarification, removal of most organisms in subsequent wastewater treatment steps was ineffective.

The effects of pH, temperature, and concentration on ozone disinfection of wastewater were defined (Paper No. 53, USA); it was favored by high pH, high temperature, and increasing ozone residual over the 0.1 to 0.2 mg/L range.

The studies on indicator organisms and on mechanisms for assurance of reliable, safe, reclaimed water supplies are areas of concern for those areas of the USA where water is potentially in short supply and wastewater needs to be reclaimed. Indicator assays especially need to be further developed to provide reliable, rapid assurance of valid quality control at reasonable cost and within the capability of most laboratories.

Eutrophication --

The use of terbutryn for controlling water hyacinth in South Africa and its side effects were detailed (Paper No. 56). Similar research on the effect of various herbicides on aquatic weeds could be directed at solving some of the problems plaguing some reservoirs and lakes in the USA. The release of nutrients, and subsequent algal growth, changes in water quality, depletion of dissolved oxygen, and the effect on water treatment must be considered.

An Australian author (Paper No. 28) indicate that estuarine algal blooms are controlled by storm events and non-point sources of nutrients. The contention is also made that it is a fallacy to try to control eutrophication through nitrogen control alone.

Land Disposal --

No yield reductions of grass and grain crops were found when, instead of commercial fertilizers, sludges containing Al, Fe, and Ca added to remove phosphorous from wastewater (Paper No. 59, Canada) were used as fertilizers. Discussers pointed out the potential of problems with heavy metals, especially at adverse pH levels.

The use of activated sludge and aerated lagoon systems to treat landfill leachate was described in laboratory and full-scale studies in Germany (Paper No. 60). The discussers pointed out the inherent variability of leachate and its unfavorable impact on such treatment systems and suggested the consideration of leachate recycling and land treatment as more resilient processes.

With recent strong emphasis on lagoons and other simple land disposal alternatives for domestic wastewater treatment, the actual field percolation experience noted in Paper No. 61 should be valuable to researchers. The Dan Region experiment in Israel is a rather elaborate wastewater reclamation project and the results from this project should be studied for its utility in the USA.

Methane Fermentation --

The effect of model toxicants (chloroform and potassium cyanide) on anaerobic systems was reported (Paper No. 63, USA). Through acclimation and/or the use of an attached-growth reactor, toxicity was lessened about 50-fold. Other toxicants are under study.

Water-Quality Modelling and Management --

Modelling studies covered least-cost optimization for area-wide wastewater management (Paper No. 64, USA), statistical data-analysis techniques in multidimensional water quality analysis of a river basin (Paper No. 65, France), river basin management strategy (Paper No. 66, Netherlands), and a mechanistic model to predict effects of river impoundment (Paper No. 67, Germany).

Work on water quality modelling of Kobe Harbor (Paper No. 29, Japan) leads to the important observation that optimum management dictates that the management model be selected prior to design of the modelling effort to insure the collection of all data pertinent to the model.

Urban Runoff --

Data on urban stormwater quality have been developed over three years in seven areas of Finland (Paper No. 68). Over 15 quality factors have been correlated with at least seven independent variables.

Gas Transfer --

A fundamental analysis of the transfer of oxygen and nitrogen such as occurs under the conditions existing in a U-tube aerator was developed (Paper No. 2, Norway, USA). The analysis provides means for understanding and preventing fish death due to gas embolisms.

Another author (Paper No., 26, USA) presented practical design information on O₂ transfer in U-tube aeration. With the recent attention being given to "deep shaft treatment," this information should be of broad interest. For example, it was shown that the U-tube requires capture and recycle of off-gases if it is to be used in an efficient manner as the absorption system for an oxygen activated sludge system.

Sludge Treatment --

An empirical analysis was presented to simplify scale-up of sludge flotation equipment (Paper No. 1, Canada). Use of a dissolved oxygen meter was advocated as a convenient means for monitoring the air-to-solids ratio in flotation.

Toxic Materials --

The applicability of foam fractionation to remove specific pollutants such as heavy metals was considered (Paper No. 3, France). An illustration was removal of humic and fulvic acids from a drinking water supply.

In discussion of work on removal of mutagens in wastewater reclamation systems (Paper No. 38), a Japanese participant reported that his colleagues were using the "REC assay" which utilizes special mutants of *E. coli* having a deficiency in a DNA-repair enzyme. If a toxicant causes DNA damage, the mutant bacteria will not survive. This assay was reported to be more sensitive than the Ames Test (it does not measure the same effect, however).

Biological Wastewater Treatment --

South African (Paper No. 4) and Swiss (Paper No. 5) researchers suggested means for analyzing the performance of activated sludge systems that take into account the differences

between particulate and dissolved organic material. Particulate organic material was considered to be rapidly incorporated into sludge floc and then degraded slowly (Paper No. 5). Conventional practice involves the assumption that particulate and dissolved organic material degrade in similar fashions.

An alternative to the conventional means of considering endogenous respiration in biological systems was proposed (Paper No. 4). The alternative is a "death-regeneration" formulation which involves consideration of a high death rate followed by cell lysis and resynthesis of cellular material into the viable cells.

The observed total length of filamentous organisms per unit volume was suggested (Paper No. 6, USA) as being the principal factor influencing the settlability of activated sludge. Settling data obtained from 12 different wastewater treatment plants were reported to have the same dependence on filament length.

Oxygen consumption rate was shown to be a better parameter than organic loading intensity for control of the activated sludge process (Paper No. 7, Denmark). This is because the food storage capacity of activated sludge systems smooths out fluctuations in loading.

An anaerobic fixed-film reactor was demonstrated (Paper No. 13, USA) to be an effective means for degradation of catechol. Granular activated carbon formed the medium in the reactor, and it was continuously bioregenerated.

In a German Plant, exceptionally deep (26 m) aeration tanks were used to maximize gas transfer and minimize off-gas volume (Paper No. 14). The approach was advocated in cases where off-gas treatment is necessary.

Attempts at rigorous modelling of fixed film biological processes (Paper Nos. 15, 16, and 17; Japan, Denmark, USA) revealed that critical information (such as diffusion coefficients, etc.) must be obtained to permit development of relevant models.

The significance of nonbiological mechanisms for removal of organic compounds in biological wastewater treatment plants was emphasized (Paper No. 19, Switzerland). Volatization and adsorption on or absorption in activated sludge particles are prevalent nonbiological mechanisms.

Investigators from three countries, (Workshop on Odor and Airborne Contaminants from Wastewater Collection and

Treatment) Lue-Ming (USA), Pahren (USA), Strand (Australia), Gelu (Canada), Henry (Australia), and Carroll (Canada) agreed that several epidemiological investigations, some including air monitoring, have failed to demonstrate any microbiological health hazard caused by aerosols from wastewater treatment processes. These negative results should be considered to be significant, but they may not apply in countries in which waterborne infectious diseases are more common or where agricultural use of untreated or partially treated wastewater is more extensive.

Nitrogen and Phosphorus Removal --

The suitability of a wide variety of organic industrial wastes as carbon sources for biological denitrification was evaluated (Paper No. 8, Canada). Twenty-seven of the 30 industrial wastes tested gave denitrification rates equal to or greater than those observed using commercial methanol. The potential cost savings is about 60¢/kg of nitrogen removed.

Biological denitrification in fluidized bed reactors attracted appreciable attention. Two different groups of researchers (Paper Nos. 9 and 10, USA and Canada) presented results of attempts to model the complex performance of fixed-film fluidized bed biological reactors.

Use of multiple tanks in series was suggested (Paper No. 12, Japan) as a means for achieving nitrification with decreased alkali costs and improved reaction kinetics.

French research on use of biological fluidized beds for removal of nitrates from potable water supplies was described (Paper No. 11). In discussion of the paper, advantages of autotrophic denitrification to avoid possible introduction of excess organic compounds into water was described.

The need for close attention to outward transport of the products of biological reaction through biofilms was emphasized (Paper No. 16, Denmark). In the case of denitrification in fixed film reactors, accumulation of nitrogen gas can have an appreciable effect on performance.

A graphical means for predicting the quality of effluent from processes involving lime addition was presented (Paper No. 22). The technique involves a modification of the Caldwell-Lawrence diagram.

A Swiss study (Paper No. 20) indicated possible savings in chemical costs for phosphorus precipitation by

integration of filtration into the phosphorus removal process (as opposed to using filtration for final polishing).

Danish researchers (Paper No. 18) showed significant influence of calcium and bicarbonate concentrations on phosphorus removal using iron or aluminum salts. Theoretical and experimental studies showed the reduction in phosphate solubility with an increase in calcium activity or a decrease in bicarbonate activity.

Physical-Chemical Treatment --

French experience in using a turbidimeter to automatically control chemical dosages at physiochemical treatment plants was reported (Paper No. 23). Significant savings in chemical dosages were realized.

Rather fundamental work on the existence of "internal waves" within clarifiers was presented (Paper No. 25, Canada). Consideration of this phenomenon could open a new approach to improving clarifier design and offer possibilities for achieving better performance from both new and existing units.

A novel adsorption system was described (Paper No. 42, USA) in which hexavalent chromium is removed by activated carbon attached to rotating disks submerged in a mixed reactor. Advantages cited included increased adsorption rate, ease of carbon separation and pH control and ability to use different carbons in different sections to adsorb, for example, any trivalent chromium present.

Water Reuse --

It was demonstrated (Paper No. 21, South Africa) that, depending upon the intended use of renovated wastewater, alternative chemical coagulating agents can serve significantly varying purposes.

Groundwater --

Canadian scientists (J. Sykes -- Workshop on Groundwater Contaminants) have developed and verified a model for the migration of pollutants from landfill leachates. The model was said to give useful predictions of the direction and rate of travel of plumes of polluted groundwater.

Ocean Disposal --

As would be expected, many views on the propriety of ocean disposal of sewage sludge were expressed (Paper No. 30). Representatives from Great Britain expressed fear that such

practices would be banned. Session consensus was that ocean disposal of sludge was acceptable with proper site selection and monitoring.

The method for use of radioactive isotopes in determining horizontal and vertical dispersion of two sewage fractions in near-shore coastal waters was described (Paper No. 33, Australia). This technique could be useful in studies of the dispersion of oil and grease in USA coastal waters.

Follow-up work on the Minamata Bay incident was reported (Paper No. 34). The movement of mercury from Minamata Bay into the ocean has been extensively studied; interestingly, the migration to the sea has accelerated in recent years. From the work, future movement appears to be predictable and a generally applicable sediment migration model is proposed.

Developments Outside of Formal Sessions

Much of the beneficial exchange of technical information occurring at professional meetings takes place outside of the formal sessions. At international conferences, the opportunities for such effective information transfer are considerable. Recognizing this potential, participants in the development of this report were asked to submit comments obtained from such interactions with water pollution researchers from other nations. Comments of possible interest to EPA, not part of the formal conference program, are summarized in this section. These comments have been identified with an individual participant and do not necessarily reflect the views of USANC.

Biological Wastewater Treatment --

There yet remains a need to develop and use a unified system of nomenclature particularly in the area of biological treatment kinetics (Pohland). A working group, chaired by P. Grau, Czech. Science and Technology Society, Czechoslovakia, has been formed under IAWPR auspices to develop a system of symbols for use in biological waste treatment research and technology (Jenkins).

The use of fixed film systems is increasing with various modifications being introduced including the upflow anaerobic sludge bed system being advanced by Lettinga in the Netherlands (Molof).

The concern about energy has revitalized interest in recovery and use of methane produced during anaerobic treatment of industrial wastes and municipal and industrial sludges (Malina). Considerable research on anaerobic processes is being conducted in Czechoslovakia (Randall).

In the discussion of formulating mathematical models describing biological processes, many felt that the model development for activated sludge has pretty well run the gamut and research emphasis should be on formulating predictive models for alternative biological processes. For example, there is little substantive information on widely applicable models for the rotating biological contactor process, the activated biofilter process, and the powdered activated carbon treatment approach using both biological oxidation and carbon adsorption mechanism. One topic that was of particular interest to many of the participants was the lack of heat-loss predictive models for the biological processes discussed herein. For example, biochemical oxidation of complex industrial wastewaters is extremely temperature sensitive. However, there is a paucity of literature describing predictive equations for heat loss in the various biological processes and using various types of aeration equipment. The development of heat loss equations for the alternative biological processes was therefore considered to be appropriate. The ability to maintain heat of a given wastewater treatment system in a cold climate, for example, might fully justify the selection of this particular process over alternative processes based on its ability to provide a higher quality effluent during colder times of the year (Ford).

Investigators from Germany, Austria and the Netherlands are cooperating in solving the problem of filamentous bulking by developing an identification key for filamentous microorganisms encountered in activated sludge and continuing in attempts to isolate filamentous microorganisms from a variety of treatment plants as well as to grow them in pure cultures to determine their physiological and nutritional characteristics. Some findings indicate that treatment plants without primary sedimentation are more likely to experience bulking problems, longer primary basin retention times without septicity results in less sludge bulking, and filamentous microorganisms occur either at low or at high organic loading rates (Sezgin).

Nitrogen and Phosphorus Removal --

There is a continuing interest on the removal of nutrients, namely, nitrogen and phosphorus, in most areas of the world. The impact of these constituents on receiving waters with corresponding levels of eutrophication has been discussed for a long period of time, and it was the general opinion that continuing emphasis on the following topics should be maintained: (1) the biological removal of phosphorus; (2) continuing research relative to the enhancement of biological nitrification and denitrification. It was the consensus that most of the chemical methods of phosphorus removal have been

thoroughly researched and there will be minimal technological advances in this area. Most of the research needs to center around the enhancement of biological removal of phosphorus and establishing the need for additional research for removal attained synergistically while applying physical/chemical removal methods necessary for water reclamation and achieving effluent qualities consistent with more stringent quality standards. For example, the determination of enhanced phosphorus removal from various biological configurations and post treatment using filtration and activated carbon would be one area where this topic could be researched more extensively (Ford).

In terms of nitrification, the research area of developing a more definitive approach in controlling and enhancing the biological removal of ammonia was discussed. Many agree that the effect of environmental factors (pH, temperature, specific toxicants, etc.) has been thoroughly researched and there is little need to further investigate such impacts. A better understanding of the nitrifying bacteria and their responses to design and operating conditions, however, is fully justified in terms of new research. Most agreed that the denitrification area also is subject to more extensive research and development, particularly on a full scale (Ford).

Considerable experience with the removal of both nitrogen and phosphorus in biological systems without chemical addition is being gained in South Africa. In particular, the Bardenpho process and similar modifications of activated sludge are apparently operating successfully according to information available from H.N.S. Wiechers of the Water Research Commission and G. V. R. Morais of the Univ. of Capetown. Although still controversial, chemical mechanisms of phosphorus removal are being recognized (Randall).

In south Germany, about 200 treatment plants use ferric salts for phosphorus removal without the frequency of sludge bulking problems experienced by other plants. Iron may inhibit the growth of filamentous microorganisms and/or act as a weighing agent or flocculant to increase settleability (Sezgin).

Considerable interest was exhibited in determining the mechanism(s) of phosphate removal by activated sludge in excess of that which would be predicted by "normal" biological growth and which occurs in several commercially available processes. Two ad hoc meetings of delegates from South Africa, USA, Switzerland, Denmark, Israel and Canada were held during the conference, but no definite mechanism could be advanced. It was recommended that any data collected from operating plants aimed at the resolution of enhanced phosphate removal should include at a minimum, C/N/P ratio, Ca, Mg, alkalinity, P, Fe, Al and pH data. Attempts should also be made to

identify and characterize solids present by techniques as X-ray crystallography and X-ray fluorescence. The meeting resolved to form a study group under the aegis of IAWPR to meet again at the Biennial IAWPR Conference in Capetown. James Bernard of South Africa serves as the contact person for the group (Jenkins)

Interest in the nature of organic phosphorus compounds is being re-established in Ireland (Minear).

Physical-Chemical-Biological Treatment --

Evidence from South Africa continues to demonstrate that water produced by the Stander wastewater reclamation plant (an advanced physical-chemical-biological treatment plant) meet all South African drinking water standards, which are comparable to USA standards. Comparisons of organic constituents with several water supplies in South Africa indicated that the reclaimed water was of superior quality. Mutagenic effects data, as measured by the Ames test, also supported the effectiveness of such treatment to meet drinking water standards (Kavanaugh).

The use of chlorine dioxide in France for disinfection at the seacoast appears equal to chlorination and much less than ozonation in cost while generating less trihalomethanes (Lash).

As cited in a formal paper Swiss researchers have demonstrated that activated sludge plants removed several industrial organic contaminants by nonbiological means - air stripping and absorption into the biomass. Additional efforts by Matter-Mueller, Gujer, Giger and Stumm will be directed at the efficiency for volatile organics removal of various gas-transfer systems (bubble aeration, trickling filters) used in biological treatment (Kavanaugh).

Point and Nonpoint Sources --

Ongoing studies in Australia with freshwater reservoirs have shown the importance of hydraulic mixing resulting from stormwater runoff events in stimulating subsequent algal blooms. Current efforts are attempting to assess whether the subsequent growth stimulation is primarily the result of nutrient release from sediments with subsequent water column mixing, or the inflow of nutrient-laden stormwater that increases the surface layer concentrations. Experience with pollution control efforts indicate that point-source nitrogen removal by controlled algal bloom is neither practical nor necessary (Randall).

Use of cost effectiveness analysis in water pollution control planning is gaining interest in Japan. The concept of trade off between point source control and nonpoint source control is being investigated from a systems analysis point of view (Ahmed).

Renovation and Reuse --

There continue to be substantial differences in opinion regarding acceptable practices for the reclamation and reuse of wastewater. The South Africans have demonstrated leadership in the implementation of potable reuse and in the development of analytical monitoring techniques for water renovation treatment systems. A greater degree of international cooperation is warranted in establishing criteria for acceptable renovation and reuse practices (Linstedt).

Toxic and Hazardous Substances --

Considerable interest and concern were evident regarding the nature and fate of toxic and hazardous substances in the environment, although these topics were addressed only in a peripheral manner at the conference (Pohland). Preliminary investigations by Steve Hurley in Canada are concentrating on the nature and fate of heavy metals in wastewater treatment plants (Minear).

In South Africa, the effluents of synthetic fuel plants before and after treatment are monitored for toxic substances. Since the presence of heavy metals and possible toxic substances in industrial and municipal sludges limits potential application of these sludges to agricultural lands, pretreatment of industrial wastes prior to biological treatment to remove heavy metals and possible refractory organic substances is an area where research is needed (Malina).

According to Stumm of Switzerland, toxicity testing should be preceded by an assessment of potential pathways of toxicants in the environment and in biota based on a knowledge of physical-chemical properties, rate of biodegradation, and rate and amount of bioaccumulation (Jenkins).

The issue of trace organic species which might exhibit long term health effects is one of wide spread concern. More and more information regarding the presence of toxic, carcinogenic, and/or mutagenic agents in the effluents of municipal and industrial waste treatment facilities is emerging. However, there is concern that information is insufficient to assess impacts on public health and that technologic and economic resources necessary to provide their removal are lacking (Weber).

An informal discussion group representing Germany, the Netherlands, Canada and the USA commented on the need for more emphasis on control and disposal of toxic water constituents (Goodgame).

As the interim final regulations for RCRA have been published in the USA, there is obviously interest in what research needs will be mandated by this very comprehensive statute. In discussion of this statute with representatives from UK, they indicated that the UK has had RCRA-like regulations for some time. The definition and classification of what constitutes a "hazardous" material is paramount in terms of required research, and even though this topic has been the subject of much study to date, there are still research needs. The storage, transport, and ultimate disposal of hazardous wastes, of course, is a primary concern of the developing countries, specifically those having significant chemical, petrochemical and refining production capacities. Considering the generation, transport and disposal of hazardous wastes is a precursor to research in groundwater contamination as well as land treatment (Ford).

Cost/Risk Analyses - Methods of Quantification --

Inflationary pressures, negative balances of payment, and the necessity for enhancing the gross national product often at the expense of the environment to offset these negatives were discussed with many of the participants. This directly relates to environmental control research specifically in light of increasing costs and energy demands to provide various levels of effluent quality control. As costs and energy demands for environmental cleanup become more severe, it was suggested that more emphasis should be placed on quantifying cost/risk analyses. To put this in more specific terms, the probabilities of achieving certain effluent quality from wastewater treatments receiving either municipal or industrial wastewaters as related to the corresponding cost demands and energy demands should be developed in a quantifiable and uniform way (Ford).

Impact of Local and Federal Regulations on International Waterways --

There was considerable discussion on developing a better approach in coordinating local and national effluent quality regulations where international waterways are affected. This is hardly a new topic, but in many cases, the coordination of statute writing, enforcement and coordination where international waterways are involved, has been inadequate. Three waterways that were specifically discussed included the Rhine River, the Danube River, and the North American Great

Lakes. It was the general opinion that research should not be limited to technical aspects of water and wastewater but should include institutional research relative to coordinating these regulations on international waterways thus justifying a logical place in the IAWPR realm of research activities (Ford)

Applied Versus Theoretical Research --

Many participants mentioned concern for the balance of applied and theoretical research. The consensus of those individuals with whom the subject was discussed was that the emphasis should be reduced on theoretical research while applied research specifically related to national needs should be underscored. Of course, some made a case for the need for basic research when long-term needs are considered (Ford).

Activated Carbon Research --

This topic is getting full attention both in the USA and in many of the advanced countries of the world, primarily because of the concern of discharge of potentially carcinogenic, mutagenic or teratogenic compounds into the environment. Many of these compounds can be removed by activated carbon, and this has generated a broad interest in this treatment approach. The interest in the USA is currently centered around the use of powdered activated carbon and enhancement of biological processes based on the 1984 BCT and BAT standards. This topic was discussed extensively with representatives from the Federal Republic of Germany, South Africa, United Kingdom, and Australia. The Australians have been interested in the use of their brown coal as an activated carbon source for several years and are currently investigating this possibility. The abundance of bituminous and lignite coal in the USA and the apparent advantages of using powdered carbon as compared to granular carbon in terms of energy demand justify the need for more extensive research using such a system. This research need is appropriate in the USA, based on specific statutes currently on the books, and the promising results of selected bench, pilot, and full-scale applications to date (Ford).

Groundwater Contamination --

Hydrogeology is a discipline that has become more and more prevalent in the field of water pollution and environmental control primarily because of the contamination of groundwaters from various land disposal sites. Although the hydraulics of groundwater flow have been studied for years and the discipline is well advanced, groundwater chemistry and treatment of contaminated groundwaters is still a relatively unresearched field. There was a great deal of interest in this discipline

based on discussions with various conference participants. Both recovery well pumpage -- surface treatment of contaminants with surface disposal or reinjection approaches -- and in situ treatment were the topics of conversation (Ford).

Land Treatment --

The successful land treatment of liquid and solid wastes was discussed to some extent and there were varied interests in this topic. The developing countries as well as some of the advanced countries are particularly interested in land treatment as it is the most energy-effective and economical approach in treating wastewaters in many cases. However, the total environmental impact, particularly on groundwater, is not documented, so most of the environmental questions center around such an impact (Ford).

Ocean Disposal --

The discussion of ocean disposal centered around four basic subtopics, namely, characterization of waste sources (regional or subregional inventories of organic, inorganic and radioactive material discharges), determination of chemical/physical and biological characteristics of effluents discharged to the ocean, establishment of testing protocols for materials when injected into coastal or ocean waters, and identification of highest priority disposal problems which deserve early attention. There are many other aspects of ocean disposal including classification of marine mixing processes and definition of disposal concepts with corresponding cost analyses. This is a vital and appropriate international topic of water and pollution control research. The USA is particularly active in the areas of ocean disposal through various agencies including the Marine Board of the National Academy of Sciences. There was significant international interest in this topic (Ford).

Offshore Drilling Activities --

The significance of increased ocean drilling both in coastal waters and in the outer continental shelf was emphasized. There is a pronounced interest in this topic, particularly the impact of drilling muds and cuttings discharged to waters contiguous to drilling platforms. Countries involved in offshore drilling, such as Norway, UK, Australia, USA, and others, have a vested interest in the determination of the optimal handling of these materials while minimizing the environmental impact on receiving waters or contiguous areas (Ford).

Impact of Alternative Energy Source Usage on the Environment --

This is a particularly appropriate subject based on the recent decision in the USA to initiate a massive coal conversion synfuels program. This has many implications in terms of environmental impact, specifically in water use and wastewater discharge. Most interests of other countries in this area were from those adjacent to the USA as to what air and water impact this conversion program will have on their respective countries. Brief discussions with the host Canadians indicated that most of the questions from the Canadians centered around the air impacts over Canadian property and the wastewater impacts on receiving waters bordered by the USA and Canada (Ford).

Research in Operator Training --

Many conference attendees indicated that the performance achieved by water pollution control plants in their countries did not reach the design goal. Two areas suggested as causes of the inadequate plant performance were: (1) inadequate design treatment of flow-load variation as they affect unit performance; and, (2) lack of adequate training of plant operating personnel. The suggestions were made by many attendees that: (1) design engineers need to prepare more complete information on operating skills and education needed to operate plant units properly; (2) statewide or areawide training courses need to be offered on a regular, scheduled-in-advance basis; and, (3) in-plant training apprentice programs need to be developed. Many suggested that research be directed at evaluating the degree of improvement - and the techniques required therefore - that can be obtained by a concerted program to upgrade operation and operator training. (Baumann).

Microbiology and Virology --

A need was recognized by international representatives to establish a group to review water virology and thereby increase communication among those researchers working in the area. A study group on Water Virology has been established by IAWPR (Roy).

Low Technology Systems --

Discussions with representatives of developing nations revealed a need for efficient, reliable, low technology systems of low manpower intensity. The need was considered particularly urgent for industrial waste treatment (Reynolds).

PROGRAMME
10th INTERNATIONAL CONFERENCE
 of the
INTERNATIONAL ASSOCIATION
 on
WATER POLLUTION RESEARCH

June 23-27, 1980
 Sheraton Centre
 Toronto, Canada

PARTICIPATING ORGANIZATIONS

International Association on Water Pollution Research
 Canadian National Committee of the IAWPR
 Chemical Institute of Canada
 Environment Canada
 National Research Council of Canada
 Ontario Ministry of the Environment
 The University of Toronto

PROGRAMME
10^e CONFÉRENCE INTERNATIONALE
 de
L'ASSOCIATION INTERNATIONALE
DE LA RECHERCHE
 sur
LA POLLUTION DE L'EAU

23-27 juin 1980
 Sheraton Centre
 Toronto, Canada

ORGANISMES PARTICIPANTS

Association internationale de la recherche sur
 la pollution de l'eau
 Comité national canadien de l'AIPE
 Institut de chimie du Canada
 Environnement Canada
 Conseil national de recherches du Canada
 Ministère ontarien de l'Environnement
 Université de Toronto

WELCOME FROM THE CONFERENCE PRESIDENT

We in Canada are stewards of a very considerable portion of the world's freshwater bodies. It was therefore with great pleasure and a considerable feeling of responsibility that we accepted the honour to host the 10th Biennial Conference of the International Association on Water Pollution Research from 23rd-27th June 1980.

On behalf of the International Governing Board, the Canadian National Committee of IAWPR, and the water pollution researchers in Canada, I have the honour to welcome you to this conference which will be of major importance to all those engaged or interested in water pollution research throughout the world.

This biennial event provides a unique international platform for the presentation of new knowledge in all aspects of water pollution, and the scientific programme promises to be of merit and wide interest. Additionally we are offering during the Conference a series of technical excursions to show something of our work and achievements and for those who will be spending an extra day or two in Canada, we have organized a range of pre-and post-conference seminars and technical tours.

Mindful of the value of personal contacts and friendships made outside the conference halls we have also arranged a very full social programme for registrants and their families.

Everyone involved in the preparation of this event will do everything that is possible to make your visit professionally rewarding and personally enjoyable.

Philip H. Jones
 Professor of Civil Engineering
 University of Toronto

**BIENVENUE DE LA PART DU PRÉSIDENT
 DE LA CONFÉRENCE**

Le Canada compte une très grande part des étendues d'eau douce du globe. C'est donc avec un grand plaisir et un sens aigu des responsabilités que le Canada a accepté l'honneur d'être l'hôte de la 10^e Conférence biennale de l'Association internationale de la recherche sur la pollution de l'eau qui a lieu du 23 au 27 juin 1980.

Au nom du Conseil international de direction, du Comité national canadien de l'AIPE et des chercheurs canadiens en matière de pollution de l'eau, j'ai l'honneur de vous accueillir à cette conférence qui sera d'une grande importance pour tous ceux qui sont engagés ou intéressés dans la recherche sur la pollution de l'eau partout dans le monde.

Cette biennale est un événement international unique où sont présentées les nouvelles connaissances sur tous les aspects de la pollution de l'eau, et le programme scientifique promet d'être de qualité et très intéressant. En outre, nous proposons au cours de la conférence une série de visites techniques où seront présentés certains de nos travaux et de nos réalisations, et pour ceux qui prolongeront d'un jour ou deux leur séjour au Canada, nous avons organisé différents séminaires qui précéderont et suivront la conférence, ainsi que différentes visites techniques.

Conscients de la valeur des contacts personnels et des amitiés établis à l'extérieur des salles de conférence, nous avons aussi organisé un programme d'activités sociales des plus complets à l'intention des participants et de leur famille.

Tous ceux qui ont participé à la préparation de cet événement feront tout en leur possible pour rendre votre séjour profitable sur le plan professionnel et agréable sur le plan personnel.

Philip H. Jones
 Professeur de génie civil
 Université de Toronto

SCHEDULE OF EVENTS

Sunday, June 22

- 14:00-20:00 Registration — Concourse Level
- 19:00-22:00 Meet and Greet Reception — Civic Ballroom

Monday, June 23

- 08:00 Registration — Concourse Level
- 10:00 Opening Ceremonies — Ballroom
- 14:00 Technical Sessions — East, Centre and West Ballrooms
- 18:15 Tour and reception, Ontario Science Centre

Tuesday, June 24

- 09:00 Technical Sessions — East, Centre and West Ballrooms
- 09:00 Technical Excursion — TE 1
- 14:00 Technical Sessions — East, Centre and West Ballrooms
- 14:00 Technical Excursion — TE 2
- 15:00 Workshop 1 — Essex Ballroom
- 18:30 Reception — Rotunda, City Hall

Wednesday, June 25

- 09:00 Technical Sessions — East, Centre and West Ballrooms
- 09:00 Technical Excursion — TE 3
- 14:00 Technical Sessions — East, Centre and West Ballrooms
- 14:00 Technical Excursion — TE 4
- 15:00 Workshop 2 — West Ballroom
- 18:30 Reception — Ballroom Lobby
- 20:00 Banquet, Ballroom

Thursday, June 26

- 09:00 Technical Sessions — East, Centre and West Ballrooms
- 09:00 Technical Excursion — TE 5
- 14:00 Technical Sessions — East, Centre and West Ballrooms
- 14:00 Technical Excursion — TE 6
- 15:00 Workshop 3 — West Ballroom

Friday, June 27

- 09:00 Technical Excursion — TE 7

OPENING CEREMONIES

CÉRÉMONIES D'OUVERTURE

SHERATON CENTRE (Ballroom)

Monday/lundi, 23 June/juin

- 10:00 Entertainment featuring the Canadian Brass/
Divertissement donné par le Canadian Brass
- 10:25 Arrival of/Arrivée de
Honourable Pauline McGibbon O.C., B.A., LL.D., D.U., D.
Hum L., D. Litt S., B.A.A. (Theatre/Théâtre) Hon.
F.R.C.P.S. (C), Lieutenant-Governor of Ontario/
Lieutenant-gouverneur de l'Ontario
- 10:30 Introduction of Lieutenant-Governor/
Présentation du Lieutenant-gouverneur

Official Opening of Conference/
Ouverture officielle de la conférence
Honourable Pauline McGibbon
- 10:45 Welcome by/Allocution de bienvenue
Honourable Harry Parrot, Minister of the Environment,
Province of Ontario/Ministre de l'Environnement de l'On-
tario
- 11:00 Welcome by/Allocution de bienvenue
Stuart Hodgson, Chairman of the International Joint Com-
mission of the Great Lakes/Président de la Commission
mixte internationale des Grands-Lacs
- 11:20 Remarks by the President of IAWPR/
Commentaires du Président de l'AIPE
Bertil Hawerman (Sweden/Suède)
- 11:30 O Canada
Departure of Vice Regal Party/
Départ du Lieutenant-gouverneur et de sa suite
- 11:35 Adjournment of Opening Ceremonies/
Clôture des cérémonies d'ouverture
- 11:45 Musical interlude by Canadian Brass/
Intermède musical par le Canadian Brass
- * Audience are requested to stand during arrival of the Vice Regal
Party, during their departure and during the playing of the Vice
Regal Salute.

L'assistance doit se lever lors de l'arrivée et du départ du
Lieutenant-gouverneur ainsi que pendant l'exécution du salut.

TECHNICAL SESSIONS

SÉANCES TECHNIQUES

Monday/lundi 23 June/juin

HALL A (East Ballroom)

- | | | |
|----------|-----------------------|------------|
| Chairman | J. K. Bewtra (Canada) | Président |
| Recorder | N. Kosaric (Canada) | Secrétaire |
- 14.00 1. Assessing Flotation Behaviour of Different Types of Sewage Suspensions.
R. Gehr, J. G. Henry (Canada)
Discussion: R. I. Dick (US)
- 14.45 2. Predicting Oxygen and Nitrogen Absorption Rates from Submerged Suspensions of Gas Bubbles
T. Bilstad (Norway), E. N. Lightfoot (US)
Discussion: G. F. Bennett (US)
- 15.30 3. Applications of the Bubble Fractionation to Water and Wastewater Treatment.
J. Mallevialle, M. Mielton, C. Tauzin, M. Roustan, H. Roques (France)
Discussion: P. B. B. Vosloo (S. Africa)

Monday/lundi 23 June/juin

HALL B (Centre Ballroom)

- | | | |
|----------|--------------------|------------|
| Chairman | S. Iwai (Japan) | Président |
| Recorder | E. R. Baumann (US) | Secrétaire |
- 14.00 25. The Use of Flow Contractions to Improve Clarifier Performance.
P. L. Silveston, J. F. Cordoba-Molina, R. R. Hudgins (Canada)
Discussion: D. Carlson (US)
- 14.45 26. Pilot Performance of Deep U-Tubes.
R. E. Speece, D. Gallagher, Ch. Krick, R. Thompson (US)
Discussion: J. F. Malina (US)
- 15.30 27. Performance of Finned Channel Separator
N. Tambo, K. Hashimoto, M. Sugahara, T. Hasegawa, T. Onitsuka (Japan)
Discussion: P. N. Paul (UK)

Monday/lundi 23 June/juin

HALL C (West Ballroom)

- | | | |
|----------|--------------------------|------------|
| Chairman | P. Grau (Czechoslovakia) | Président |
| Recorder | A. K. Barnes (S. Africa) | Secrétaire |
- 14.00 49. Transport of Heat and Nutrients Across a Thermocline.
P. J. de Bruijn, L. Lijklema, G. van Straten (Netherlands)
Discussion: B. A. Benedict (US)
- 14.45 50. The Impact of Sewers on the Nutrient Budget of Lake George, N.Y.
D. B. Aulenbach, N. L. Clesceri, J. R. Mitchell (US)
Discussion: L. H. James (S. Africa)
- 15.30 51. Nonpoint Quantification and its Role in Lake and Stream Water Quality Planning.
R. Ahmed, R. Schiller (US)
Discussion: Mr. Desbordes (France)

TECHNICAL SESSION

SÉANCE TECHNIQUE

Tuesday/mardi 24 June/juin

HALL A (East Ballroom)

- | | | |
|----------|--------------------------|------------|
| Chairman | W. Stumm (Switzerland) | Président |
| Recorder | P. Grau (Czechoslovakia) | Secrétaire |
- 09.00 4. A General Model for the Activated Sludge Process Part I
P. L. Doid, G. A. Ekama, G. v. R. Marais (South Africa)
Discussion: W. Masschelein (Belgium)
- 09.45 5. The Effect of Particulate Organic Material on Activated Sludge Yield and Oxygen Requirement.
W. Gujer (Switzerland)
Discussion: D. Jenkins (US)
- 10.30 Break/Pause
- | | | |
|----------|---------------------------|------------|
| Chairman | L. Lijklema (Netherlands) | Président |
| Recorder | H. Ehrhardt (Netherlands) | Secrétaire |
- 11.00 6. The Role of Filamentous Microorganisms in Activated Sludge Settling.
M. Sezgin (US)
Discussion: W. O. Pipes (US)
- 11.45 7. Evaluation of Operational Benefits to the Activated Sludge Process using Step Feed Control Strategies.
P. E. Sørensen (Denmark)
Discussion: J. L. Barnard (S. Africa)
- 12.30 Lunch/Déjeuner
- | | | |
|----------|----------------------|------------|
| Chairman | L. Ullmgren (Sweden) | Président |
| Recorder | A. B. Wheatland (UK) | Secrétaire |
- 14.00 8. Industrial Waste Carbon Sources for Biological Denitrification.
H. D. Monteith, T. R. Bridle, P. M. Sutton (Canada)
Discussion: Y. Sekikawa (Japan)
- 14.45 9. Kinetic Model of Biological Denitrification in a Fluidized Bed Biofilm Reactor (FBBR).
L. T. Mulcahy, W. K. Shieh, E. J. La Motta (US)
Discussion: S. Elmaleh (France)
- 15.30 10. Kinetics of Biological Fluidized Bed Wastewater Denitrification.
J. P. Stephenson, K. L. Murphy (Canada)
Discussion: R. L. Irvine (US)

TECHNICAL SESSION

SÉANCE TECHNIQUE

Tuesday/mardi 24 June/juin

HALL B (Centre Ballroom)

- | | | |
|----------------------|---|-------------------------|
| Chairman
Recorder | K. Baalsrud (Norway)
E. Gjessing (Norway) | President
Secrétaire |
| 09.00 | 28. Some Factors involved in the Occurrence and Limitation of Algal Blooms in an Australian Estuary
C. W. Heath, I. C. Smalls, D. Cannon (Australia)
Discussion: P. J. Ashton (S. Africa) | |
| 09.45 | 29. Application of Ecological Dynamics for Eutrophication Control in Kobe Harbor Area
I. Morioka (Japan)
Discussion: W. E. Scott (S. Africa) | |
| 10.30 | Break/Pause | |
| Chairman
Recorder | L. Menda (Italy)
W. Gujer (Switzerland) | President
Secrétaire |
| 11.00 | 30. Long-Term Changes in Benthic Fauna Resulting from Sewage Sludge Dumping into the North Sea.
H. Caspers (Germany)
Discussion: H. Fish (UK) | |
| 11.45 | 31. Variability of Bacterial Counts in Coastal Waters
A. L. H. Gameson (UK)
Discussion: E. M. Nupen (S. Africa) | |
| 12.30 | Lunch/Déjeuner | |
| Chairman
Recorder | A. Hernandez (Spain)
T. Gill (UK) | President
Secrétaire |
| 14.00 | 32. The Role of Bottom Deposits in the Oxygen Regime of a Polluted Estuary.
A. James (UK)
Discussion: W. Bischofsberger (Germany) | |
| 14.45 | 33. Investigations into Sewage Grease Behaviour in Coastal Waters.
A. Davison, J. F. Eassey, J. J. Varjavandi, K. M. Warner (Australia)
Discussion: A. E. Thorne (S. Africa) | |
| 15.30 | 34. Movement of Mercury from Minamata Bay into Yatsushiro Sea.
A. Kudo, Sh. Miyahara, D. R. Miller (Canada)
Discussion: T. Bilstad (Norway) | |

TECHNICAL SESSION

SÉANCE TECHNIQUE

Tuesday/mardi 24 June/juin

HALL C (West Ballroom)

- | | | |
|----------------------|--|-------------------------|
| Chairman
Recorder | L. Com (France)
C. Gomella (France) | President
Secrétaire |
| 09.00 | 52. Evaluation of Acid-Fast Bacteria, <i>Candida albicans</i> , Enteric Viruses and Conventional Indicators for Monitoring Wastewater Reclamation Systems.
W. O. K. Grabow, J. S. Burger, E. M. Nupen (South Africa)
Discussion: H. I. Shoval (Israel) | |
| 09.45 | 53. Inactivation of Enteroviruses by Ozone
D. Roy, R. S. Engelbrecht, P. K. Y. Wong, E. S. K. Chian (US)
Discussion: E. M. Nupen (S. Africa) | |
| 10.30 | Break/Pause | |
| Chairman
Recorder | G. J. Stander (S. Africa)
G. G. Cillie (S. Africa) | President
Secrétaire |
| 11.00 | 54. Study of a Pour Plate Technique for the Enumeration of Coliform Organisms in Surface Water.
J. Vial, Ch. Geoffray (France)
Discussion: L. Evison (UK) | |
| 11.45 | 55. Efficiency of Ultrafiltration for the Isolation of Enteric Viruses and Coliphages from Large Volumes of Water in Studies on Wastewater Reclamation.
E. M. Nupen, N. C. Basson, W. O. K. Grabow (South Africa)
Discussion: Mr. Vilagines (France) | |
| 12.30 | Lunch/Déjeuner | |
| Chairman
Recorder | G. Bjork (Sweden) | President
Secrétaire |
| 14.00 | 56. The Chemical Control of the Water Hyacinth (<i>Eichhornia crassipes</i> (Matr.) Solms).
P. J. Ashton, W. E. Scott, D. J. Steyn (South Africa)
Discussion: Mr. Gilbert (France) | |
| 14.45 | 57. The Stimulation of Autotrophic Production by Urban Stormwater-borne Nutrients.
T. J. Grizzard, R. N. Waterman, C. W. Randall, R. C. Hoehn (US)
Discussion: Ms. Rizet (France) | |
| 15.30 | 58. The Sensitivity to Phosphorus and Nitrogen Loads of Lake Rotorua, New Zealand.
R. A. Hoare (New Zealand)
Discussion: P. J. Ashton (S. Africa) | |

TECHNICAL SESSION

SÉANCE TECHNIQUE

Wednesday/mercredi 25 June/juin

HALL A (East Ballroom)

- | | | |
|----------------------|--|-------------------------|
| Chairman
Recorder | C. D. Parker (Australia)
L. W. Henry (Australia) | President
Secrétaire |
| 09 00 | 11. Denitrification of Water for Human Consumption
Y. Richard, A. Leprince, G. Martin, C. Leblanc (France)
Discussion: Y. Sekikawa (Japan) | |
| 09 45 | 12. Biological Nitrogen Removal by Step-Feed Process
Y. Miyaji, M. Iwasaki, Y. Sekigawa (Japan)
Discussion: J. F. Andrews (US) | |
| 10 30 | Break/Pause | |
| Chairman
Recorder | F. M. Middleton (US)
K. D. Linstedt (US) | President
Secrétaire |
| 11 00 | 13. Continuous Bioregeneration of Granular Activated Carbon during the Anaerobic Degradation of Catechol.
M. T. Suidan, W. H. Cross, M. Fong (US)
Discussion: W. J. Weber Jr. (US) | |
| 11 45 | 14. Bayer Tower Biology — An Efficient, Low Noise and Odor-Free Process for Biological Waste Water Treatment
E. Schellmann (Germany)
Discussion: G. Hincke (Germany) | |
| 12 30 | Lunch/Déjeuner | |
| Chairman
Recorder | G. T. G. Scott (US)
T. H. Goodgame | President
Secrétaire |
| 14 00 | 15. Nitrification Kinetics in a Rotating Biological Disk Reactor
Y. Watanabe, M. Ishiguro, K. Nishidome (Japan)
Discussion: A. Margaritis (Canada) | |
| 14 45 | 16. Practical Problems Related to Nitrogen Bubble Formation in Fixed Film Reactors.
P. Harremoës (Denmark)
Discussion: P. M. Sutton (Canada) | |
| 15 30 | 17. Design of Fixed-Film Processes with Steady State-Biofilm Model
B. E. Rittman, P. L. McCarty (US)
Discussion: J. H. Reynolds (US) | |

TECHNICAL SESSION

SÉANCE TECHNIQUE

Wednesday/mercredi 25 June/juin

HALL B (Centre Ballroom)

- | | | |
|----------------------|---|-------------------------|
| Chairman
Recorder | W. F. Lester (UK)
A. van Haute (Belgium) | President
Secrétaire |
| 09 00 | 35. Development and Application of a Technique for the Determination of the Molecular Mass Distribution of Organic Compounds in Water.
O. O. Hart (South Africa)
Discussion: N. Tambo (Japan) | |
| 09 45 | 36. The Fate of Organic Micropollutants through an Integrated Wastewater Treatment/Water Reclamation System.
J. F. J. van Rensburg, A. Hassett, S. Theron, S. G. Wiechers (South Africa)
Discussion: N. K. Pilkington (S. Africa) | |
| 10 30 | Break/Pause | |
| Chairman
Recorder | K. R. Imhoff (Germany)
R. Leschber (Germany) | President
Secrétaire |
| 11 00 | 37. Reactions of Ozone with Aromatics in Dilute Aqueous Solution: Reactivity and Biodegradability of Oxidation Products
B. Légube, B. Langlais, M. Doré (France)
Discussion: L. D. Lash (US) | |
| 11 45 | 38. Removal of Mutagenic Compounds in a Wastewater Reclamation System Evaluated by Means of the Ames Salmonella/Microsome Assay.
R. Denkhaus, W. O. K. Grabow, O. W. Prozesky (South Africa)
Discussion: A. Margaritis (Canada) | |
| 12 30 | Lunch/Déjeuner | |
| Chairman
Recorder | G. Heinke (Canada)
J. W. G. Rupke (Canada) | President
Secrétaire |
| 14 00 | 39. An Appraisal of Bacterial Indicators of Pollution in Sea Water.
L. M. Evison (UK), E. Tosti (Italy)
Discussion: Mr. Montiel (France) | |
| 14 45 | 40. Study of Partially Neutralised Aqueous Aluminium Chloride Solutions: Identification of Aluminium Species and Relation between the Composition of the Solutions and their Efficiency as a Coagulant.
J. Y. Bottéro, J. E. Poirier, F. Fiessinger (France)
Discussion: C. R. O'Melia (US) | |
| 15 30 | 41. Evolution of Organic and Mineral Pollutants in Surface Water under the Effect of Lagooning.
F. Erb, J. Dequidt, A. Brice, J. l'Hopitault, A. Philippo, J. N. Pommery (France)
Discussion: J. W. Smith (US) | |

TECHNICAL SESSION

SÉANCE TECHNIQUE

Wednesday/mercredi 25 June/juin

HALL C (West Ballroom)

- | | | |
|----------------------|---|-------------------------|
| Chairman
Recorder | L. E. Janson (Sweden)
B. Ericsson (Sweden) | President
Secrétaire |
| 09:00 | 59. Lysimeter and Field Studies on Land Application of Wastewater Sludges
M. D. Webber, Y. K. Soon, T. E. Bates (Canada)
Discussion: E. J. Hall (S. Africa) | |
| 09:45 | 60. Operation and Design of Biological Leachate Treatment Plants
R. Stegmann, H.-J. Ehrig (Germany)
Discussion: F. G. Pohland (US) | |
| 10:30 | Break/Pause | |
| Chairman
Recorder | T. Yoshida (Japan)
A. Margaritis (Canada) | President
Secrétaire |
| 11:00 | 61. Treatment Effects and Pollution Dangers of Secondary Effluent Percolation to Groundwater
E. Idelovitch, M. Michail (Israel)
Discussion: | |
| 11:45 | 62. Nitrogen Removal in a Subsurface Disposal System
A. Andreoli, R. Reynolds, N. Bartilucci, R. Forgione (US)
Discussion: O. Langenegger (S. Africa) | |
| 12:30 | Lunch/Déjeuner | |
| Chairman
Recorder | R. Canham (US) | President
Secrétaire |
| 14:00 | 63. The Response of Methane Fermentation to Cyanide and Chloroform
J. Yang, R. E. Speece, G. F. Parkin, J. Gosset, W. Kocher (US)
Discussion: A. Molof (US) | |

TECHNICAL SESSION

SÉANCE TECHNIQUE

Thursday/jeudi 26 June/juin

HALL A (East Ballroom)

- | | | |
|----------------------|--|-------------------------|
| Chairman
Recorder | E. J. Hall (S. Africa)
M. R. Henzen (S. Africa) | President
Secrétaire |
| 09:00 | 18. A General Equilibrium Model for the Precipitation of Phosphate with Iron and Aluminium
E. Arvin, G. Petersen (Denmark)
Discussion: H. N. S. Wiechers (S. Africa) | |
| 09:45 | 19. Non-Biological Elimination Mechanisms in a Biological Sewage Treatment Plant
C. Matter-Müller, W. Gujer, W. Giger, W. Stumm (Switzerland)
Discussion: P. Balmer (Sweden) | |
| 10:30 | Break/Pause | |
| Chairman
Recorder | D. Newsome (UK)
H. Fish (UK) | President
Secrétaire |
| 11:00 | 20. Optimal Advanced Treatment and Phosphorus Removal by Deep Bed Filtration
H. Gros, B. Morgeli (Switzerland)
Discussion: M. Kavanaugh (US) | |
| 11:45 | 21. A Comparative Study of Various Coagulants for the Renovation of Secondary Effluents
L. R. J. van Vuuren, G. G. Cillie, J. van Leeuwen, J. Prinsloo (South Africa)
Discussion: T. L. Theis (US) | |
| 12:30 | Lunch/Déjeuner | |
| Chairman
Recorder | J. Bernard (France) | President
Secrétaire |
| 14:00 | 22. Lime Treatment of Wastewater: Development and Application of a Simple Graphical Technique for Predicting the Chemical Composition of Lime-Treated Secondary Effluent
H. N. S. Wiechers, R. E. Loewenthal, G. v. R. Marais (South Africa)
Discussion: R. A. Minear (US) | |
| 14:45 | 23. Physico-Chemical Treatment of Wastewater — Control of Reagent Additions by Pollutational Load to be Treated
P. Marchandise, J. P. Legendre (France)
Discussion: R. K. Chalmers (UK) | |
| 15:30 | 24. Flocculation of Waste Emulsions using Polyelectrolytes
C. Axberg, A.-M. Wennerberg, P. Stenius (Sweden)
Discussion: Z. Yoshino (Japan) | |

TECHNICAL SESSION

SEANCE TECHNIQUE

Thursday/Jeudi 26 June/juin

HALL B (Centre Ballroom)

- | | | |
|----------------------|---|-------------------------|
| Chairman
Recorder | W. Masscheken (Belgium)
Mr. Wilms (Belgium) | Président
Secrétaire |
| 09 00 | 42 Activated Carbon Processes for the Treatment of Chromium (VI) — containing Industrial Wastewaters
A. R. Bowers, C. P. Huang (US)
Discussion: B. M. Van Vliet (S. Africa) | |
| 09 45 | 43 The Removal of Nitrogen from an Inorganic Industrial Effluent by Means of Intensive Algal Culture
F. Hendricks, J. Bosman (South Africa)
Discussion: R. J. Stevens (UK) | |
| 10 30 | Break/Pause | |
| Chairman
Recorder | N. Matsche (Austria)
H. Fleckseder (Austria) | Président
Secrétaire |
| 11 00 | 44 Biological Nitrogen Control of Coke Plant Wastewaters
T. R. Bridle, W. K. Bedford, B. E. Jank (Canada)
Discussion: N. Kosanic (Canada) | |
| 11 45 | 45 Adsorption and Ion Exchange Processes for Treatment of White Water and Waste Water of Paper Mills
C. H. Mobius (Germany)
Discussion: S. Hallquist (Sweden) | |
| 12 30 | Lunch/Déjeuner | |
| Chairman
Recorder | H. Leskeläe (Finland)
P. E. Persson (Finland) | Président
Secrétaire |
| 14 00 | 46 Inorganic Mercury-Bituminous Coal Sorption Interaction in Water
M. P. Pandey, M. Chaudhuri (India)
Discussion: S. Kiemetson (US) | |
| 14 45 | 47 Water Quality Changes and Clearing Requirements for Impoundments in Arctic and Subarctic Regions
D. W. Smith (Canada)
Discussion: P. Odendaal (S. Africa) | |
| 15 30 | 48 Heavy Metals in the Ruhr River and their Budget in the Catchment Area
K. R. Imhoff, P. Koppe, F. Dietz (Germany)
Discussion: R. L. Sinks (US) | |

TECHNICAL SESSION

SEANCE TECHNIQUE

Thursday/Jeudi 26 June/juin

HALL C (West Ballroom)

- | | | |
|----------------------|--|-------------------------|
| Chairman
Recorder | P. E. Sørensen (Denmark)
N. Nyholm (Denmark) | Président
Secrétaire |
| 09 00 | 64 Least-cost Optimization for Areawide (208) Wastewater Management using Mixed Integer Programming
K. J. Phillips, S. R. Kellogg, E. J. Bultrami, T. O. Carroll (US)
Discussion: H. C. Stegmann (S. Africa) | |
| 09 45 | 65 The Use of Multidimensional Analysis in the Comparison of the 1976 vs. 1971 River Seine Basin Surveys
Y. Le Foll, A. Lesouéfi (France)
Discussion: B. J. Adams (Canada) | |
| 10 30 | Break/Pause | |
| Chairman
Recorder | R. L. Earle (New Zealand)
H. R. Hughes (New Zealand) | Président
Secrétaire |
| 11 00 | 66 Combating River Pollution taking the Rhine as an Example
C. van der Veen, J. Huizinga (Netherlands)
Discussion: W. H. J. Hattingh (S. Africa) | |
| 11 45 | 67 The Application of the Biocenotic Model for the Prediction of the Effects of an Impoundment of Flowing Water
M. Boes (Germany)
Discussion: E. Herricks (US) | |
| 12 30 | Lunch/Déjeuner | |
| Chairman
Recorder | M. Sergin (Turkey/US)
O. O. Hart (S. Africa) | Président
Secrétaire |
| 14 00 | 68 Urban Runoff Quality in Finland and its Dependence on some Hydrological Parameters
M. J. Melanen, R. H. Laukkanen (Finland)
Discussion: Mr. Friant (France) | |

WORKSHOP 1**ATELIER 1****ESSEX BALLROOM****15:00****Tuesday/mardi 24 June/juin**

Convenor

T. C. Hutchinson
(Canada)

Convocateur

The Ecological and Health Significance of Heavy
Metals in the Aquatic Environment

Panelists/panelistes: J. Kramer, K. Murphy, P. Stokes, P. Anderson

Note: A limited number of tickets will be available for active participants of this workshop at the registration desk on a first-come first-served basis. Attendees without tickets will be admitted to the hall until it is filled. The discussion session in this workshop will be impromptu and no translation services will be available.

Note: Un nombre limité de billets pour cet atelier seront offerts aux participants au bureau d'inscription, les premiers arrivés seront les premiers servis. Les personnes qui n'ont pas de billet seront admises dans le hall jusqu'à ce que ce dernier soit rempli. La séance de discussion pour cet atelier sera informelle et aucun service de traduction ne sera fourni.

WORKSHOP 2**ATELIER 2****HALL C (West Ballroom)****15:00****Wednesday/mercredi 25 June/juin**

Convenor

H. I. Shoval
(Israel)

Convocateur

Odour, Airborne Contaminants and Aerosols from
Wastewater Collection and TreatmentPanelists/panelistes: H. Pahren (US), W. Jacobowski (US),
A. B. Wheatland (UK), S. Shaub (US),
C. Lue-Hing (US)**WORKSHOP 3****ATELIER 3****HALL C (West Ballroom)****15:00****Thursday/jeudi 26 June/juin**

Convenor

A. van Haute
(Belgium)

Convocateur

Ground Water Contaminants from Land Disposal of Residues

Panelists/panelistes: Dr Verheyden (Belgium),
J. Sykes (Canada), Dr Young (UK),
R. Griffin (US)

TECHNICAL EXCURSIONS

The following technical tours have been organized for the benefit of delegates and accompanying persons at **no charge**. All interested persons are requested to pick up their tickets from the registration desks as soon as possible. The reservation of tickets will close 48 hours before the event. **Tickets are limited.**

All excursions leave from the York Street entrance of the Sheraton Centre. Participants are asked to gather in the hotel lobby at least 15 minutes before departure time.

TUESDAY, JUNE 24

TE1 Experimental Plant for Resource Recovery (half-day)

The Ontario Ministry of the Environment's \$15.0 million Experimental Plant for Resource Recovery, a production-size research and development facility, is the cornerstone of the Province's Resource Recovery Program. Unit operations within the Plant include: shredding, air separation and classification, screening, magnetic separation, and composting. Design process rate is 40 tons/hour. Unique and innovative features of the Experimental Plant include process control and monitoring, a data collection system, environmental controls, and provision for visitors.

DEPARTURE: 09:00 hours

TE2 Canada Centre for Inland Waters (half-day) Wastewater Technology Centre (WTC)

The WTC develops and implements water pollution control technology programs for industrial and municipal wastewaters across Canada. This unique Centre comprises fixed and mobile facilities for laboratory experiments in addition to facilities for bench-scale process development. Pilot plant studies are carried out to develop new technologies for wastewater treatment and sludge and residue management.

DEPARTURE: 14:00 hours

WEDNESDAY, JUNE 25

TE3 Canada Centre for Inland Waters (half-day) Hydraulics Research Laboratories (HRL)

The HRL provide the finest facilities for studies in environmental hydraulics. Highlights are highly specialized equipment such as the large wind-wave flume, 115 meters long, a large sediment transport flume, and a cold chamber with an environmental flume for ice studies. In addition, a large towing tank provides a calibration and testing service.

DEPARTURE: 09:00 hours

TE4 Metro Toronto Highland Creek Sewage Treatment Plant (half-day)

The Highland Creek Sewage Treatment Plant serves an area of approximately 13,880 hectares and a connected population of about 265,000. The original plant, which was completed in 1956, had a treatment capacity of 18,200 m³/24h. Plant extensions have increased the plant's treatment capabilities to 145,500 m³/24h. Further extensions are under construction to bring the plant's capacity up to 218,000 m³/24h and to add sludge incineration facilities. The Highland Creek Sewage Treatment Plant accomplishes the treatment of wastewater by the conventional methods of screening, aerated grit removal, gravity settling and the biological processes of aerobic oxidation of colloidal and dissolved solids and anaerobic digestion of sludge solids. The digested sludge is dewatered by centrifuging prior to land filling. The plant extension to 145,500 m³/24h incorporates waste activated sludge thickening by dissolved air flotation and the Porteous heat treatment method for sludge conditioning prior to sludge dewatering and incineration.

DEPARTURE: 14:00 hours

THURSDAY, JUNE 26

TE5 Duffin Creek Pollution Centre (half-day)

The present phase of the Duffin Creek Pollution Control Centre is the first stage of a treatment plant which will expand to an ultimate capacity of 727,400 m³/24h to serve a projected population of 800,000 after the year 2000. The present treatment facility has flow capacity of 181,800 m³/24h. The treatment of the wastewater is carried out using the conventional activated sludge process preceded by screening, grit removal by settling, and primary sedimentation. The sludge from the treatment process is subjected to anaerobic digestion and is then dewatered using belt filters. The dewatered sludge cake is incinerated in fluid bed incinerators and the excess energy is recovered through steam turbines for in-plant use. The Duffin Creek incineration complex is the largest of its kind in the world for municipal applications.

DEPARTURE: 09:00 hours

TE6 Easterly Filtration Plant

Easterly Filtration Plant, Metropolitan Toronto's newest water supply facility, will commence operation early 1980 with an initial capacity of 455,000 cubic metres per day.

Taking raw water from an intake, 18 m deep and 2,680 m offshore, the treatment includes pre-chlorination, coagulation with ferric chloride and polymer, in-line blending, flocculation, direct filtration, post-chlorination, de-chlorination with sulphur dioxide, ammoniation and fluoridation. The back wash waste water is clarified before being returned to the lake, the sludge being pumped to the nearby Highland Creek Treatment Plant.

The plant is designed to provide a high level of hydraulic flexibility and ultimate computer control.

Due to its unique location on the Scarborough Bluffs overlooking Lake Ontario, the plant has been constructed vertically with the intake well and raw water pump room located 10 stories underground, below the treated water pumping station.

DEPARTURE: 14:00 hours

FRIDAY, JUNE 27

TE7 Canada Centre for Inland Waters (full-day)

This excursion will consist of a tour of the Canada Centre for Inland Waters including both the Wastewater Technology Centre and the Hydraulic Research Laboratories as described in TE2 and TE3. A nominal charge will be made for lunch.

DEPARTURE: 09:00 hours

PRE-AND POST-CONFERENCE SEMINARS

PS1 Non Point Source Pollution

Date: Thursday 19th June and Friday 20th June

Location: McMaster Univ., Hamilton,
Ontario L8S 4C7

Programme: Soil-Contaminant Interactions

Discussion of various physical, chemical and biological processes occurring. Included will be measurement techniques and a presentation of laboratory and field case studies.

Groundwater Contaminant Modelling

Theory of contamination modelling and discussion of various modelling techniques followed by presentation of case studies. The principal concern will be agricultural contaminants.

Rural Ecosystems

Discussion of transport mechanisms and modelling endeavours. A delineation of the problem will be presented.

Urban Ecosystems

Evaluation of various modelling techniques and a discussion of available corrective measures. Case studies to be presented.

Organiser: Bill Snodgrass, Dept. of Civil Eng., McMaster Univ., Hamilton, Ont. L8S 4C7

Fee: US \$100 members, US \$125 non-members

PS2 Nuclear Power and Wastewater Management (Cancelled)

PS3 Ecotoxicology and the Aquatic Environment

Date: Tuesday 17th June to Thursday 19th June

2 days plus one optional field trip

Location: Guild Inn, Toronto and University of Toronto

Programme:

1. Biological and chemical assays for toxic substances
Presentations and discussions of the scientific and practical values of fish, invertebrates, algae for bioassay of organic and inorganic toxins.
2. Microbial transformations of toxic substances, the use of microcosms in toxicological research
3. Monitoring and modelling toxic materials in aquatic ecosystems
An evaluation of the concept of biological monitors for environmental contaminants. The dose-commitment model.
4. Local tour: Canada Center for Inland Waters, Burlington
Simulators and aquatic toxicology facilities.
5. Workshops — arising from the major seminar topics
6. Optional post-conference field trip to Killarney and Sudbury, Ontario. Water bodies acidified and/or metal contaminated by local and regional inputs of pollutants. Ontario Ministry of the Environment lake reclamation programme. International Nickel Company tailings reclamation.

Organizers: P. M. Stokes, Institute for Environmental Studies,
University of Toronto, Toronto, Canada M5S 1A4
Telephone: (416) 978-6526 Telex: 06-23887

G. Butler, Environmental Secretariat, National Research Council,
Ottawa, Ontario, Canada
Telephone: (613) 995-6600

Fee: Member US \$150 Non-Member US \$175

PS4 Design of Water and Wastewater Services for Cold Climate Communities

Date: Saturday 28th June and Sunday 29th June

Location: University of Alberta, Edmonton, Alberta

Programme: The Challenges and state of the art solutions for the provision of water supply and wastewater disposal for cold climate communities will be considered. Topics of current interest will include: ground conditions and thermal modelling considerations for permafrost regions, alternative utility and distribution concepts for water, fire protection, wastewater and solid waste, novel approaches to water conservation, water and wastewater treatment problems associated with cold climates and corresponding technology.

The seminar will feature contributions from leading academics and design specialists and will be structured to encourage active interchange and discussion by attendees. A half day optional visit will be conducted to Edmonton's new E. L. Smith water treatment plant and HBC wastewater treatment plant at Devon.

Registrants will be provided with information regarding travel to point of interest such as the Canadian Rockies and the Yukon and Northwest Territories which are readily accessible from Edmonton.

Organiser: Professor S. Hruday and Dr. D. W. Smith, Department of Civil Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G7

Telephone: (403) 432-5122 Telex: 037-2979

Fee: Member US \$125 Non-Member US \$150

SPECIALIZED CONFERENCE

New Developments in River Basin Management

Sunday 29th June to Thursday 3rd July
Cincinnati, Ohio

The conference will bring together professions having responsibility for the management of rivers as related to their many uses and researchers engaged in the different aspects of River Basin Management. It will be used as a forum to critically evaluate tools and policies in the use of economic incentives and regulatory sanctions, transnational experience in developing programmes to meet new challenges and the application of research in the decision-making process.

This conference is planned in accordance with discussion at the specialised conference in River Basin Management held in Essen, West Germany, September 1977, wherein it was concluded that many questions remained unanswered and a follow-up conference should be scheduled to share new information and results.

Organiser: The Ohio River Valley Water Sanitation Commission,
414 Walnut Street, Cincinnati, Ohio 45202, U.S.A.

Leo Weaver, Executive Director

Telephone: (513) 421-1151

Price: US \$160 for non-members US \$140 for members

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- H. Fish (United Kingdom/Royaume-Uni)
- *D. H. Newsome (United Kingdom/Royaume-Uni)
- P. C. G. Isaac (United Kingdom/Royaume-Uni)
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- A. Hernandez (Spain/Espagne)
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